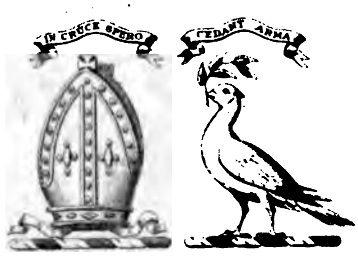
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PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

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GEOLOGISTS' ASSOCIATION.

VOLUME THE SEVENTH.

1881-2.

EDITED BY

PROFESSOR J. F. BLAKE, M.A., F.G.S.

(Authors alone are responsible for the opinions and facts stated in their respective Papers.)

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PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

ADDRESS

AT THE OPENING OF THE SESSION, 1880-81.

NOVEMBER 5, 1880.

BY THE PRESIDENT,

PROF. T. RUPERT JONES, F.R.S., F.G.S., &c.

THE GEOLOGISTS' ASSOCIATION : ITS ORIGIN AND PROGRESS.

One of the Founders of this Association, our esteemed friend and fellow-worker, the Rev. Thomas Wiltshire, writing to me in March last about the pleasant meeting we had at our *Memorial Dinner*, on the occasion of the Association having flourished for twenty-one years, and thus attained a "Legal Majority," made the following remark :—

"How different was the condition of affairs in the winter of 1858, when three or four people met together at the Working Men's College, in Great Ormond Street, to consider whether a small society could not be formed to discuss in a very modest way geological matters."

This led me to enquire further into the history of the Association—its beginning, its intentions, and its results; and, little having been printed in a continuous or connected form on this subject, I thought it would not be without interest to put together some notes on the views, endeavours, and progress of our Society, and that possibly some suggestions might arise among us for the furtherance and widening of our aims and aspirations.

In preparing these remarks on the early history of the Geologists' Association, I have been courteously assisted by the loan of Reports, Circulars or Notice-papers, and other memoranda, by Mr. Wakefield, Mr. George Potter, Mr. J. Slade, the Rev. T. Wiltshire, Prof. Tennant, Mr. Lobley, Mr. Hopkinson, and other members.

In August, 1858, there appeared in the "Geologist" of that date (at page 356) a letter, headed "Proposition for an Association of Amateur Geologists," and signed, "W. J. Haywood." It runs thus: "Sir,—I take the liberty of submitting to your consideration, for approval or otherwise, the suggestion of the advisability of young geologists (*i.e.*, young as regards their progress in the science) forming themselves into a society. If you approve of this suggestion, will you be kind enough to give it publicity in the correspondence column of your periodical? The best reasons I can adduce in support of this idea are the circumstances of my own case as a solitary student of the science. About four years ago, a perusal of Lyell's 'Elements' led me to perceive that geology was nothing less than a study of the physical history of the globe, and of the races that have successively inhabited it. Since that time I have studied the other works of Lyell, and also those of Buckland, Mantell, Miller, Page, Ansted, &c.; and this amount of theoretical knowledge, with the results of a few rambles in the Thames basin, and along the sea-coast from Ramsgate to Brighton, is all that I can boast of. I have never been able to meet with a single individual with whom I could exchange a dozen thoughts upon geology. Sometimes, indeed, I have thought that I never should be able to enjoy that pleasure; but the mere fact of the publication of the 'Geologist' is an evident proof that geology is more generally studied than I thought it was. Besides, my circumstances are such as to prevent me not only from obtaining such works as Murchison's 'Siluria,' Agassiz's 'Poissons Fossiles,' &c., but also from taking long journeys, or spending much time in the country. There are also many maps which I should like to study, but which I cannot afford to buy. Now, Sir, I doubt not there are many young men in London whose individual cases in many respects resemble mine, and were we to form a society, meeting at stated periods, we could compare notes, give account of our rambles, examine one another's fossils and minerals, exchange duplicates; whilst the subscriptions would purchase maps and books such as individually we could not

obtain; and in many ways we could be of great assistance one to another. I throw out the suggestion in a very general manner, this not being the proper occasion for entering more minutely into details; but, hoping that the idea itself will meet with your approbation, I am, Sir, yours, W. J. HAYWOOD."

The Editor appended the following statement:—"To this proposal for the association of young geologists we are disposed to give our assistance; but we should have liked to have placed something more definite before our readers, and for this purpose we wrote direct to the author of the suggestion. From some informality or incorrectness in the address our letter has been returned to us from the post-office. We can, therefore, only express our sympathy in the project, and say that we shall be happy to be the medium of communication until definite arrangements are made by the suggester and others for carrying it out."

In the September number of the "Geologist," at p. 401, the Editor states that he has "received letters for Mr. Heyward [*sic*], but cannot forward them, not knowing that gentleman's address."

In October of 1858 the "Geologist," page 446, contained a note signed "RAC-HAC," saying, "I should very much like to be a member of the proposed 'Amateur Geological Association,' and trust to hear much more about it in your next number."

At page 449 of the same number of the "Geologist" is the following note, headed, "Society of Amateur Geologists," and signed, "Geo. S. Penson":—"Dear Sir,—I read with pleasure the proposition for an Association of Amateur Geologists in a late number of your 'Geologist.' This is a thing I have long been wishing for; indeed, at the time of reading it, I had an unfinished letter upon the very subject, which I intended sending to you, but which was rendered unnecessary by the appearance of the one under consideration. I am in exactly the same position as Mr. Heyward as regards isolation, time, means, &c., and should therefore hail as a great boon the formation of such a Society, and should be most happy to unite with him in the carrying out of his excellent project. If he will oblige by furnishing me with his address I will communicate with him at once upon the subject."

At page 450, in the same Number of the "Geologist," the Editor repeats that he cannot forward letters to Mr. Heyward, not knowing his address.

In the same month (October, 1858), Mr. J. E. Wakefield (of the

Metropolitan Board of Works), and the late Mr. E. Cresy, at that time Assistant-Secretary to the Chairman, or Clerk to the Board, interested themselves in this proposed Society of Amateur Geologists. Mr. Wakefield, volunteering his services, received the letters for Mr. Heyward, and undertook the necessary correspondence. He wrote to Mr. G. S. Penson (above-mentioned), Mr. H. H. Groser, Mr. George Potter, Mr. J. E. Saunders, Mr. W. W. Armstead, the Rev. T. Wiltshire, Mr. J. Toulmin Smith, and others, all of whom readily agreed with him in the advisability of getting together a meeting of Geologists for the purpose of forming this Society of Amateurs.*

Consequently, as a first step, Mr. Wakefield, Mr. Slade, and Mr. G. Potter, being warmly interested in this contemplated organisation of geological enquirers on an economical plan, met together at Mr. Wakefield's house, Meadow Cottage, Highgate Rise, Kentish Town, on November 17, 1858. Mr. G. Potter, above-mentioned, was a resident in Highgate, and acquainted with Mr. N. T. Wetherell, Mr. J. Toulmin Smith, Mr. J. Slade, and other geologists of his neighbourhood; and heartily acquiescing in Mr. Wakefield's earnest desire to follow up the suggestions given in the "Geologist" of October, above quoted, used his best endeavours in promulgating the idea. Mr. J. E. Saunders had interested the Rev. T. Wiltshire in the project; and Mr. Slade communicated the design to Mr. F. J. Furnival among others, and he also took it up with enthusiasm. Altogether the names of about forty willing friends were numbered as being in favour of the projected Amateur Society or Association of persons interested in geological studies, and desiring to seek mutual help as learners. They were invited to a meeting, and to form a Committee. Most of the invitations were accepted, and the conference was held on Monday evening, November 29, 1858, at 2, Upper Wellington Street, Strand, where Mr. Wakefield's influence obtained the use of a large room. A unanimous desire to found and support the proposed Society was expressed, and a Provisional Committee was appointed.

There were present at this meeting:—The Rev T. Wiltshire, M.A., F.G.S. (in the chair), J. Toulmin Smith, E. Cresy, F. J. Furnival, M.A., S. J. Mackie, F.G.S., F.S.A., J. E. Saunders,

* Mr. Wakefield has favoured me with Letters and Minutes affording much information of this date; and Mr. Slade and Mr. G. Potter have kindly given me notes of their reminiscences of the time.

F.G.S., W. Hislop, F.R.A.S., John Grant, Thomas Lovick, J. Slade, F.M.S., T. A. Phillips, C. J. Morgan, W. Armstead, G. Potter, — Davis, J. S. Penson, J. E. Wakefield.

The Provisional Committee consisted of:—The Rev. T. Wiltshire, Mr. Penson, Mr. Slade, Mr. Cresy, Mr. Toulmin Smith, who was chosen Chairman, and replaced by Mr. G. Potter. Mr. Hislop was to be Treasurer, Mr. Wakefield, Hon. Secretary, and Mr. Toulmin Smith, Chairman.

Among those who entered as Members in 1858, but do not appear to have been present at this meeting, are—Professor Tennant, Hyde Clarke, A. Bott, R. Middleton, G. Perry, and W. Newall. Of country members of that date we still have James Plant (Leicester), J. Bentley (Market-Deeping), W. Curtis (Alton), F. Gotto (Leighton-Buzzard), and G. Dowker (Wingham).

On December 2nd, 1858, at three p.m., the Provisional Committee met at the Working Men's College, 45, Great Ormond Street, where, with the help of Mr. Furnival, they had the convenience of a room for their meeting. There were present—Toulmin Smith (in the chair), Rev. T. Wiltshire, Mr Hislop (Treasurer), Mr. Slade, Mr. Cresy, Mr. Wakefield (Hon. Sec.). They decided, among other resolutions, that the name of the Society should be "The Geologists' Association," and that a prospectus (1,500 copies) should be printed and circulated among the members of the Association and of the Palæontographical Society; and that an advertisement should be inserted two consecutive weeks in the "Athenæum."

The Prospectus, thus drawn up, printed, and distributed, was dated December 6, 1858. It was issued with the "Geologist" of January, 1859 (No. 13, vol. ii), as a fly-leaf at the end of the Number. For a knowledge of this prospectus I am especially indebted to Mr. J. E. Wakefield; and I may be permitted to add that I am assured that the main prop of the young Association during this trying period was our respected friend here mentioned, whose sturdy business habits kept the Members well together.

Among the earliest *printed notices* concerning the foundation of our Society, besides the Prospectus itself, is a paragraph in the January number of the "Geologist" for 1859, referring to the movements already set on foot, and reproducing the greater

part of the Prospectus which appeared on a fly-leaf in that number.

As the Prospectus and some other notices are not published in the Minutes of the Association's Proceedings, I give them here at length.

The Prospectus is headed "The Geologists' Association," and states that—

"There is no branch of Science which attracts so general—it may be said so popular—an interest as GEOLOGY; but it has been felt for some time that there is much need of a common means of intercommunication among those who, while not devoting their lives to the pursuit, yet take an active interest in its facts and teachings. The Geological Society is too far advanced in the strict course of scientific method and treatment to be found available by the increasing numbers of those who desire modestly to seek mutual help as learners, but shrink from the assumption of ranking themselves among the illustrious Professors and Masters in the Science.

"To meet this want, a number of gentlemen have organised themselves into a *Geologists' Association*, having for its special purpose the providing those means of intercommunication and mutual help.

"It is proposed to hold regular Meetings; to form a Museum of typical specimens; to afford facilities for the Collection and Exchange of specimens and for rectifying doubtfully named ones; to communicate information as to the best methods of search, localities, etc., which the experience of Members may enable them to interchange; and, in general, to enable the practical student in Geology to find a congenial place where doubts may be stated and experience exchanged; and so the pursuit of this interesting and invaluable branch of inquiry be at once made pleasanter, and freed from some of the difficulties which now attend the pursuit of it, both by individuals and localised Institutions.

"The Association will embrace Members both in town and country, its objects and usefulness being equally available by those in each, with the exception (in the latter case), of course, of the general opportunity of personal attendance at the Meetings.

"The subscriptions have purposely, and with deliberate consideration, been fixed at a rate which will exclude none from the

benefits it can give. The subscription for Town Members is *ten shillings* a year; for Country Members, *five shillings* * a year. All Members will be entitled to copies of whatever printed Minutes of the Proceedings of the Association are issued.

"The first Meeting of the Association for business will be held on an early day in January next, which will be duly announced to Subscribers, and when an Inaugural Address will be delivered by the Chairman.

"The Meeting to settle the Rules of the Association will be held on Friday, the 17th December inst., at No. 2, Upper Wellington Street, Strand, at seven o'clock in the evening *precisely*, when the attendance of all Subscribers is requested. In the meantime, it is requested that the name and address of persons wishing to join the Association may be sent (see annexed form †) *before Monday, the 13th December inst.*, to either of the under-mentioned.

"Toulmin Smith (Chairman), Highgate, N.
"William Hislop, F.R.A.S. (Treasurer), 108, St. John Street Road, E.C.
"J. E. Wakefield (Hon. Secretary), Meadow Cottage, Highgate Rise, N.W.

"*London, Dec.* 6, 1858."

The Provisional Committee next met (at 2, Upper Wellington Street, or at the Working Men's College), on December 16, 1858. Present—J. T. Smith (Chairman), T. Wiltshire, E. Cresy, W. Hislop, J. S. Penson, J. E. Wakefield.

The Prospectus had been distributed among the Members of the Association, the Palæontographical Society, the College of Preceptors, and some of the Local Societies in union with the Society of Arts, and about 100 applications for Membership had been received. The draft Rules, &c., were considered.

The same members of the Provisional Committee met also the next day, December 17, 1858, at Upper Wellington Street (?). The drafts of Report, Rules, &c., were further considered, previous to being laid before the General Meeting in the evening.

* Subsequently increased to 10s. Country Members were at first to be regarded as only "Corresponding Members;" but this plan was soon improved upon.

† Omitted here.

The First General Meeting.—In pursuance of the Resolution made at the Meeting held on 29th November, 1858, a General Meeting was held on Friday evening, 17th December, at No. 2, Upper Wellington Street, Strand, Toulmin Smith, Esq., in the chair.

The following Reports were received from the Provisional Committee and accepted, namely—on the Prospectus; on the Place of Meeting; on the Laws of the Association; Appointments of Officers, &c., and Resolutions were made thereon. Toulmin Smith was to be the President of the Association; W. Hislop to be the Treasurer; Messrs. Wakefield and Cresy * to be Honorary Secretaries. Charles Woodward, N. T. Wetherell,* T. Wiltshire, and J. Le Capellain * to be Vice-Presidents. Hyde Clarke was added to the Vice-Presidents January 11, and J. Carter, January 20, 1859.

The under-mentioned were to constitute the Committee:—J. E. Saunders, F. J. Furnival, S. J. Mackie, Thos. Lovick, J. Grant, W. N. Lawson, H. T. Kempton, W. T Rickard, J. Carter, John Pickering, Hyde Clarke, J. L. Shuter. H. Dean was added January 11, and E. Cresy, January 20, 1859.

The second printed notice of the meetings that I find is on the last page of the January number of the "Geologist,"† 1859, and is not printed in the Association's Proceedings. It refers to this General Meeting, and runs thus—

"Geologists' Association.—A meeting was held at No. 2, Upper Wellington Street, Strand, on Friday evening, the 17th December, 1858, for the purpose of organising a new Society to promote the Study of Geology and its allied Sciences.

"The means proposed are the holding of periodical meetings for reading and discussing papers and the exhibition of specimens; arrangements for the facilitating the exchange of specimens between distant members; the formation of a typical collection of fossils suited to the wants of students; the establishment of a library of reference; and the delivery of short courses of lectures.

"It was announced in the course of the proceedings that 120 applications for membership had already been received.

"The first meeting for actual work will take place early in

* These resigned their appointments soon afterwards.
† Vol. ii., No. 13, January, 1859, page 48.

January [1859], when an inaugural address will be delivered by the President [Mr. J. Toulmin Smith], and more detailed plans will be stated."

The General Committee met on Monday, the 3rd of January, 1859, at No. 45, Great Ormond Street. Present—Wiltshire (in the chair), Saunders, Hyde Clarke, Hislop, Wakefield. 1,700 revised prospectuses had been printed, and 1,250 of them sent for insertion in the "Geologist." The Library of St. Martin's Hall had been engaged for the first Ordinary Meeting. The Laws had been printed; the Forms of Application, &c, were to be prepared, and other Resolutions were made.

The General Committee met again on the 11th January at Great Ormond Street (?). Present—T. Smith (in the chair), Wiltshire, Pickering, Lawson, Lovick, Hislop, Wakefield, and Rickard. Various necessary resolutions were passed.

It is very evident that the energetic intercommunication of the earnest geologists concerned—bestirring themselves to let friends and well-wishers know of the good and thoughtful plan set afoot to bring men and their notions together on a plain and unpretending geological platform—was very successful. This success in their wishes was especially forwarded by the friendly co-operation of many members of the Palæontographical Society of London, who, at the instance of the Rev. T. Wiltshire, readily fell in with the views of the founders of a society so nearly related to, and so favourably constituted for, their own scientific objects and pursuit.

The First Ordinary Meeting of the Association was duly convened on January 11th, 1859, in the Library of St. Martin's Hall, and the doings and sayings are reported in No. 1 of the "Proceedings," and at page 95 of the "Geologist," vol. ii., 1859.

Several new members were enrolled, an Inaugural Address was given by the President, and it was stated that "within six weeks after the first conference on the subject not less than 150 gentlemen, many of them well known in connection with Geological Science, had applied for membership."

The President (Mr. J. Toulmin Smith*) spoke of the objects and advantages of the Society, and of plans for promoting and

* He resigned the Presidency on Feb. 8th, and was succeeded by the Rev. T. Wiltshire.

facilitating the collection and exchange of specimens, and for forming a good and really typical collection of fossils, for which several specimens had been already promised. He also spoke of the right naming of fossils, and against the undue use of long Latin and Greek words. Nor must we forget that he insisted upon the recognition of the "fundamental Law of Unity,* which underlies all the phenomena of Nature, as being absolutely necessary to right conclusions," and that careful observation, checked by comparison with results arrived at by others, is the only foundation for "Good Facts" and for the riddance of Falsities. Much, therefore, he observed, could be obtained by action on the *Mutual* principle of the Association.

The General Committee met at Upper Wellington Street on January 20, and again at the same place on February 8, when they adjourned until after the Ordinary Meeting in the evening, and then they met again.

At the Second Ordinary Meeting,† held at the Library of St. Martin's Hall, February 8th, 1859, Dr. Hyde Clarke (Vice-President), "sketched out a plan for the organisation of local committees in conjunction with the Association, by which the work of the Government Surveyors, and others labouring in the geological field, might be usefully followed up, and supplemented by the bringing together of new facts, as local circumstances might favour their collection.

"He believed that much remained to be done in more minute classification of the strata, &c. by local researches, and that much good was to be effected by announcements of new minerals, particularly such as would be useful as manures, for building materials, or in connection with the manufactures, as well as by notice of such operations as new mines, quarries, wells, pits, railways, roads, tunnels, &c.; of landslips, observations on springs, on thermal, superficial, and subterranean waters; electro-magnetic observations on mineral bodies; earthquakes in particular districts; the rates of erosion on shores and of new depositions; the like of river operations; of recent and ancient abrasions; and many other particulars which would be not only interesting as bearing on points of

* For a late eloquent exposition of the "Unity of Nature," see the Duke of Argyle's memoir in the "Contemporary Review," September, 1880.

† See the "Geologist," vol. ii., p. 169; and the "Proceed. Geol. Assoc.," vol. i., p. 4.

theoretical geology, but as likely to throw light on questions of great practical and economic importance.

"He adverted to the valuable services which had been rendered to the science by ladies, and mentioned several whose names were well known as accomplished geologists."

Succeeding Ordinary Meetings produced Papers of considerable interest, which were either briefly reported in the Proceedings or printed in full as separate Memoirs; and at the end of the year the First Annual Report, presented to the meeting on January 2, 1860 ("Proceedings," vol. i, p. 25), not only showed very satisfactory results for the year 1859, but defined the aim and scope of the society.

"The success of the Association has exceeded the expectations of its promoters. Originally founded with the view of placing the Science of Geology in the hands of that large class who have neither the time nor the money necessary for mastering the subject and becoming Fellows of the Geological Society of London, it has been assisted and encouraged by many well-known names, who have become Members not so much for the sake of the benefit they might themselves derive as for the aid they could impart to others.

"In the original prospectus it was stated that the Association would endeavour to promote the reading of papers, the giving of lectures, the formation of a typical collection of specimens, the exchange of fossils amongst the members, and the gathering together of sound geological books.

"In all these matters the spirit of the Prospectus has been carried out as far as the funds would permit."

In the meantime, suggestions had been made in the "Geologist" of August, 1859, vol. ii., p. 329, in a letter signed "Provincial Geologist," that a Field-Meeting should be held by the Members at least once a year, with special papers and discussions; and at page 368 of the same volume a letter from the Rev. T. Wiltshire announced that the Committee acceded to the proposition—at all events as far as settling to have one summer-day Geological Excursion in 1860.*

In both April and June, 1860, there were field-days or excur-

*Members of the Association had already enjoyed some such excursions with the Geological Classes of King's and University Colleges, under the guidance of Professors Tennant and Morris.

sions (to Folkestone and Maidstone), accordingly. They were not mentioned in the "Proceedings," but were noticed in the "Geologist," vol. iii., p. 271; and the fact of the excursions having been thrown open to the friends of the Members was commented on as evidence of the liberal enlightenment of the Committee. Charlton also is mentioned in "Proceed.," vol. i., p. 64 and 89, and in a Notice-paper, dated "May, 1861," as having been visited in 1860. In the autumn (October 15th) of 1860, a notice-paper stated that—

"The experiment of conducting Field-Lectures, which was made last summer, having appeared to give considerable satisfaction to the Members, the Committee propose to continue those Excursions on Whit-Monday, May 20, 1861."

In 1861 there were three Excursions—to Redhill and Reigate (April 9); Oxford (May 20); and the Isle of Sheppey (August 1); all reported in "Proceedings," vol. i. Subsequently long excursions, single field-days, and intervening visits to places nearer London, became common, were well attended and highly appreciated (see Notes on Excursions further on).

A Circular or Notice-paper, dated "May, 1861," states that—

"This Association, which has now been in existence for three years, was originally formed with the view of promoting the study of Geology, and affording a common means of intercommunication with those who, while not devoting their lives to the pursuit, yet take an active interest in its facts and teachings. The 'Geological Society,' it was felt, was too far advanced in the strict course of scientific method and treatment to be found available by the increasing numbers of those who, desiring modestly to seek mutual help as learners, shrink from the assumption of ranking themselves among the illustrious professors and masters of the science. The Geologists' Association has endeavoured to carry out this object by the reading of Papers, the delivery of Lectures, the exchange of Fossils among the Members, the formation of a Library and of a Typical Museum for reference, and the dissemination of the knowledge thus acquired by its printed Proceedings. In addition to these varied means of usefulness (in all of which the Association has met with very great success), it has also from time to time conducted Excursions to places of geological interest, which have proved eminently valuable in bringing the facts of Geology prominently before the student, and illustrating in an attractive form the practical portion of the Science."

It goes on to state that—

"The whole of the Lectures * and Papers read before the Meetings, together with some detached ones, have been furnished gratis, and free of postage, to every Member; that the nucleus of a Library of standard geological works has been formed; that the number of Typical Fossils already accumulated is far too great for the limited amount of cabinet-room at the disposal of the Association;" and that "it will be at once seen [that] the Geologists' Association offers many advantages."

The chief points of the above are repeated in the Circular or Notice-paper of January 5, 1863, the *Discussion* of the subject-matters of Papers being the only other point alluded to.

In the printed Laws † of December 17, 1858, the intentions of the Society are indicated by the fact that the General Committee may be sub-divided into the following and other Sub-committees:—

1. Corresponding Committee: To communicate with Members as to the Exchange of Fossils and the Supply of Specimens for the Museum. (Messrs. Rickard, Lawson, Wiltshire, Potter, and Allen; January 20, 1859.)

2. Museum Committee: To have charge of the Museum and the arrangement of Specimens, and to facilitate the naming and describing of Specimens.

3. Press Committee: To correspond with local and other Journals with a view to the dissemination of the objects of the Association, and the promotion of its interests by the publication of its Proceedings. (Messrs. Mackie, Lawson, and Cresy; January 20, 1859.)

4. Papers and Lectures Committee: To make arrangements for and examine Papers to be read before the Association. (Messrs. Wiltshire, Pickering, Mackie, and Clarke; January 20, 1859.)

5. Library Committee; To promote the formation of a Library of reference, and to have charge of the same.

6. Finance and House Committee: To carry out instructions with reference to accommodation for Meetings, etc., and such other

* Probably not the *Courses of Lectures*, but memoirs, or long papers.

† The Laws or Rules of the Association were first drawn up on December 17, 1858. They were amended February, 1859 (see "Proceed.," i., p. 3 and 5); recast in 1864 (see Annual Report for 1863); recast again in 1872 ("Proc.," ii., p. 321, &c.); amended January, 1875 ("Proc.," iv., p. 203); and there have been some subsequent modifications.

matters as involve the outlay of funds. (Messrs. Hislop, Grant, Kempton, and Saunders; January 20 and afterwards, 1859.)

This was the theoretical plan of a perfect distribution of work among members of the General Committee. In practice the General Committee, for the most part, have worked out these matters in detail as occasion required, referring for advice to those, present or accessible, best adapted to give it.

According to the Laws of the Association, as printed in 1864,* the Members contemplated—"That the object of the Association be to facilitate the study of Geology and its allied Sciences by the Reading of Papers, the Delivery of Lectures, the Formation of a Library, and the Publishing of Proceedings."

After these variations, the Law relating to the aims of the Association took the following form in 1872:—"That the object of the Association be to facilitate the study of Geology and its allied Sciences by the holding of Meetings for the Reading of Papers and the delivery of Lectures; by Excursions, the Formation of a Library, and the Publishing of Proceedings."

Thus we see that, by the year 1864, both the intention of forming a "Collection of Typical Specimens," and the notion of the "Exchange of Specimens," had fallen away, and that these were no longer recognised in the printed "Rules" as attainable objects. Nevertheless, it may be well to examine the history of these failures of intent, whilst we follow, as far as our limits allow, the success of other views and aims of the Association.

A collective view of all the aspirations of our body, whatever have been their several results, cannot but prove of interest to us; and the carrying out of these intentions from time to time comprehended several branches of a system of work, a knowledge of which can be gathered by a study of successive official or non-official statements, as well of intentions and aspirations as of methods and plans, brought before the notice of the Members.

Thus, from the sources above indicated and quoted, we find that the Founders, and many of the successive Committees of the Association, contemplated the cultivation of geological knowledge among the Members by means of *mutual help*, variously given and received, under the following heads:—

* In the Annual Report for 1863, published in 1864, we find that—"During the past year [1863] the Association has steadily progressed in the direction of its proper position, that of an Amateur Society."

I. Periodical Meetings :—Having in view—

1. Reading and Discussing Papers communicated by the Members.
2. Exhibition of Specimens with view of *(a.)* introducing New Fossils, Minerals, Rocks, &c., *(b.)* obtaining or rectifying Names.
3. Exchange of Specimens among the Members.
4. Giving and receiving information as to *(a.)* the Best Localities for fossils, *(b.)* the Best Methods of search and collection.
5. Dissemination of Geological Knowledge by printed Proceedings, separate Memoirs, and Notice-papers.

II. A Library of Reference.
III. A Museum of Typical Fossils.
IV. Field-lectures, or Excursions.
V. Courses of Lectures.
VI. Local Committees.

I propose to say a few words on each of these headings, as indicating the intentions and hopes of the Committees and Members, whether expressed by them officially or otherwise, and whether still contemplated by the existing Laws or not; and also to refer to some other points in the history and constitution of our Society which appear to me to be deserving of remark in view of our progress and the carrying out of what we have to do as Associated Geologists.

I. *Meetings.*—These were just at first limited to Town Members, Country Members being at that time only Corresponding Members; but at a very early date (March 8th, 1859) Country Members were admitted also—a wise and, of course, necessary arrangement.* Eminently field-workers, at home in the quarries and local sections, the Country Members are requisite for the bringing of fresh material for observation and thought to the dry, museum-working Londoners, who go foraging only occasionally for fossils. What would the House of Commons be without the Country Members? How could Imperial politics be perfect without Rural Constituencies? Luckily the short-sightedness (almost the only example) in the early counsels of the Founders

* In the Report of 1864 it is stated that the Meetings had been attended in the past year by a larger proportion of Country Members than had been present in former years.

of shutting out so large a number of willing Geologists from the Meetings—the recognised "Exchange" of Thought—was soon remedied; and we can be oppidans or rurals just as we like.

After its establishment by General Meeting at Upper Wellington Street, in December, 1858 (Toulmin Smith, President), the Ordinary Meetings of the Association were held in the Library of St. Martin's Hall, at first on the second Tuesday in each month (Jan. 11, Feb. 8, and March 8, 1859), and afterwards on the first Monday of each month (April 4, May 2, June 6, &c.); the Rev. T. Wiltshire, President, and J. E. Wakefield, Hon. Secretary.

1860-1. The Meetings were held at No. 5, Cavendish Square: the Rev. T. Wiltshire, President; W. N. Lawson, Hon. Sec.

1862. The Meetings were held at No. 5, Cavendish Square: Prof. J. Tennant, President; W. N. Lawson, Hon. Secretary.

1863. The Meetings were held at No. 5, Cavendish Square: Prof. J. Tennant, President; J. Cumming, Hon. Secretary.

1864-5. The Meetings were held on the first Tuesday of each month, at 32A, George Street, Hanover Square: E. Cresy, President; J. Cumming, Hon. Secretary.

1866, January to March, at George Street, Hanover Square; April to December (at 8 p.m. instead of 7 p.m.), at King's Coll., Strand, Dr. C. T. Richardson, Pres.; J. Cumming, Hon. Sec.

1867. January to March, at King's College; on and after April 5, on the first Friday of the month,* at University College: Dr. C. T. Richardson, President; J. Cumming, Hon. Sec.

1868-9-70. At University College: Prof. J. Morris, President; J. Cumming, Hon. Secretary.

1871-2. At University College: the Rev. T. Wiltshire, President; J. L. Lobley, Hon. Secretary.

1873. At University College: Dr. H. Woodward, President; J. L. Lobley, Hon. Secretary.

1874. At University College: Dr. H. Woodward, President; W. H. Hudleston, Hon. Secretary.

1875-6. At University College: W. Carruthers, President; W. H. Hudleston, Hon. Secretary.

* "Annual Report" for 1866, page 8. In the palæozoic, as in a more recent, period of the Association, at Cavendish Square and at University College, much cataclysmic action prevailed among its members, schistose cleavage, or a spliting-off, being largely developed; but strong breccias were recemented, and many Members have continued throughout.

1877-8. At University College: Prof. J. Morris, President; Dr. J. Foulerton, Hon. Secretary.

1879-80. At University College: Prof. T. Rupert Jones, President; Dr. J. Foulerton, Hon. Secretary.

Here we enjoy the use of a fine, large, and convenient apartment for our Meetings, thanks to the courtesy of the Authorities of the College; also a room for our Committee. I must say, in passing, that I venture to think that the Committee should give themselves more time (by beginning earlier) for their increasing work, and thus ensure punctuality in opening the Evening Meetings.

I. 1. *Papers and Discussions.*—With regard to the Reading and Discussing of Papers, we have to look at an important matter, namely, the nature and character of the Papers communicated to the Association.

In 1860 a Report stated that—

"The Committee would earnestly call attention to the fact that one of the main objects of the Association is the diffusion of a spirit of enquiry, among the Members, on Geological subjects; and that in no way can this object be better promoted than by the Members communicating short papers for the Monthly Meetings. The Committee would add, that in a society like the Geologists' Association, which comprises many persons who seek only to be students in the science, it is neither necessary nor desirable that the Papers should be always the fruit of original investigation, or should in every case embrace the discussion of points of novelty; communications placing the ascertained results of the labours of others in a compendious form would not be without use."

In no case has this last observation been illustrated more markedly than in a paper on the *Echinidæ* of the Chalk, communicated (Oct. and Nov. 1859) by the late Mr. E. Cresy, one of our Founders, in which "he particularly denied all claim to originality, his only merit being that of having collected into one view materials which lay scattered in a number of rare and costly works."—(See the "Geologist," vol. ii., p. 489, December, 1859.) Thus, as well by this kind of classificatory work, as by original notes, highly useful results are arrived at. In 1859 Mr. Hyde Clarke in an address to the Association gave it as his opinion that "Good facts were to be got at by the observations of the Members being brought forward at the Meetings (instead of being buried in Note-books), and there discussed and compared, and then, if good,

added to the common stock for the use of science, and for the production of knowledge fit for practical application."

In accordance with what has been stated above, we find that the communications made to the Association are broadly divisible into two kinds:—1st, those in which the authors give *résumés* or summaries of discoveries and conclusions already arrived at, and go over old ground, pointing out various subjects and points of interest—and under this heading the reports of visits made by the Associates to special localities and to geological museums are not the least in importance; and 2ndly, those papers which offer original information. The Association may well be proud of many such papers, of both classes, that have been read at the Meetings and published in the Proceedings.

It would be invidious to mention the titles of any such papers in particular. Good and useful as the majority of these are, other communications remain enumerated in the Annual Reports by title only, owing to the want of pecuniary means at one period of the Association's existence. For instance—Papers read in 1865:—

Early Geologists and their opinions, by the Rev. T. Wiltshire.

Geological Evidences of the existing domesticated Animals, by C. C. Blake.

Note, No. 3, Microscopic Geology, by W. Hislop. (Printed afterwards, "Proceed." i, p. 386.)

Notes on New-Scotland and New-Brunswick, made in 1864, by E. Cresy.

Excursion to the Isle of Wight, by W. H. Leighton.

Geology of the neighbourhood of Balmoral, by J. Crombie.

Geology of the neighbourhood of Farringdon, by C. Evans.

The Sussex Earthquake of April 30, 1864, by Capt. Noble.

Excursion to North Wales, by A. Bott.

Shingle Banks, by C. Tomlinson.

See also the lists of papers read in the five succeeding years, 1865-69, in the respective Annual Reports.

The Proceedings from January, 1865, to February, 1870, were not published by the Association.* Some notes and reports, however, belonging to this period are to be found in the "Geological Magazine" thus;—

* The first volume of the "Proceedings" ends with the Minutes of Proceedings at the Conversazione on January 24th, 1865; and vol. ii begins with the Minutes of the Ordinary Meeting on February 4th, 1870. The

"Geol. Mag." vol. iv., 1867, p. 561, Nov. 1, Cephalopoda, by the Rev. T. Wiltshire (abstract); vol. v., 1868, p. 33, Dec. 12, 1867, Crustacea, H. Woodward; vol. vi., 1869, p. 331, June 2, Excursion to Guildford, C. J. Meÿer; p. 427, Aug. 2, Excursion to Hunstanton, Prof. Morris; vol. vii., 1870, p. 91, Dec. 8, 1869, the Huelva Mining District in Spain, S. R. Pattison.

Other notices occur in Mackie's "Geological and Natural-History Repertory," 1867 thus :—

Proceedings of the "Geologists' Association" published as part of the "Geological Repertory," 1867 ; a fragment :—

Proceedings of Societies—

I. On the Past, Present, and Future of Geology. By C. T. Richardson, M.D. (Address, 6 Feb., 1866.) Page 1.

II. On the Geological Evidences of the Present Domesticated Animals. By C. C. Blake. (Read 7 Feb., 1865.) P. 6 (also at page 1 of another issue).

III. On a Specimen of Lepidotus Fittoni. By Arthur Bott. (Read in 1866.) P. 12.

IV. Notes on the Starr Hills of the Lancashire Coast. By John Rofe. (Read in 1866.) P. 13.

V. On Certain River-bars and Lagoons on the Coast of New Zealand. By R. J. L. Guppy. (Read in 1866.) P. 16.

VI. The Sussex Earthquake of April 30, 1864. By Capt. Wm. Noble. (Read in 1865.) P. 21.

method and extent of the early "Proceedings" are best shewn by the following Table :—

PROCEEDINGS OF THE GEOLOGISTS' ASSOCIATION, VOL. I.

	No.		Session		pages
The Covers are missing or were not issued.	No.	1.	Session	1859-60	pages 1-10
	,,	2.	,,	,, ,,	,, 11-18
	,,	3.	,,	,, ,,	,, 19-24
	,,	4.	,,	,, ,,	,, 25-48
	,,	5.*	,,	,, ,,	,, 49-64
	,,	6.	,,	1860-61	,, 65-116
	,,	7.	,,	1861-62	,, 117-168
The Covers are marked "Vol. I." and "5, Cavendish Square."	,,	8.	,,	,, ,,	,, 169-246
	,,	9.	,,	1862-63	,, 247-312
The Covers are marked "Vol. I." and George Street, Hanover Square."	,,	10.	,,	1863-64	,, 313-372
	,,	11.	,,	1864-65†	,, 373-420

* This No. begins with the Proceedings of April 2, 1860.

† The Proceedings (Conversazione) of January 24th, 1865. are the last in this No. The Title page of vol. i. is also dated 1865. The Index was made, I am informed, by Mr. Lobley, the Editor in 1871, who began the second volume, and completed vol. i, with the Index, so that it could be bound-up.

VII. On the Arenig and Llandeilo Groups. By H. Wyatt-Edgell. (Read in 1866.) P. 24.

VIII. On an Excursion to the Isle of Wight. By W. H. Leighton. (Read in 1865.) P. 28.

IX. Sketch of the Geology of Farringdon. By C. Evans. (Read in 1865.) P. 33.

X. Speculations on Possible Physical Causes for the Alterations of the Earth's General Climate and Atmospheric Temperature. By S. J. Mackie. (Read in 1866.) Only 5 lines, p. 40.

Moreover several Memoirs were printed separately at the cost of the Association, especially between 1865 and 1870, as Supplemental to Vol. I. of the "Proceedings;" namely—

I. J. Toulmin Smith. The Finding of True Facts. Read 11 January, 1859.

II. Hyde Clarke. On Geological Surveys by Members of the Association. Read 8 March, 1839.

III. Rev. T. Wiltshire. On the Red Chalk of England. Read 4 April, 1859.

IV. N. T. Wetherell. On some peculiar markings on broken surfaces of flints. Read 6 June, 1859.

V. Rev. J. M. Crombie.* The geological relations of the Alpine Flora of Great Britain. Read 7 June, 1867.

VI. Rev. T. Wiltshire.* On the chief groups of the Cephalopoda. Read 1 November, 1867.

VII. C. J. A. Meÿer.* On the Lower Greensand of Godalming. Read 4 December, 1868.

VIII. H. Woodward.* Man and the Mammoth. Read 1 January, 1869.

IX. T. Rupert Jones.* On the Palæozoic Bivalved Entomostraca. Read 7 May, 1869.

X. John Morris. Lead-bearing Districts of the North of England. Read 4 June, 1869.

XI. Reports of Excursions [in 1869]. *Anon.*

XII. C. Evans. On some sections of Chalk between Croydon and Oxtead. Read 7 January, 1870.

XIII. G. Dowker. Chalk of the Isle of Thanet. Read 7 May, 1870.

XIV. A. Tylor.* On Quaternary Gravels. From the

* These papers are referred to in the Annual Report 1869 (published in 1870) as having been printed and circulated in that year.

"Quart. Journ. Geol. Soc.," 1869. Reprinted at the expense of the Geologists' Association, as a memoir useful to the Members.

XV. J. L. Lobley. Mount Vesuvius, 1868. Published by Stanford as a separate work, of which Mr. Lobley liberally gave a large number of copies to the Members.

Perhaps the greatest point of divergence between *our* Society and the leading Geological body in England is that the latter deals (for reasons that are unquestionably well founded) in entirely *new* matter. So learned and so leading a body should undoubtedly makes its primary object the spread of new ideas, new theories, and new facts. Its position is such as to make it take the lead in creating and assimilating new matter; whilst our own more humble efforts, bringing fewer new facts to the front, lead to the grouping of generalities and the distribution of certified knowledge. Our Association thus aims at a different end, not less important nor less useful (I really believe) than that of the Geological Society;[*] and by this we can materially aid the general spread of our special Science. As new facts accumulate, new hypotheses, ceasing to be mere conjectures, arrange themselves in the received theories of Geological Science; and it becomes necessary for some earnest workers to take in hand the successive arrangement of the knowledge acquired, and tabulate, so to speak, the stages that have been reached, and the groups of useful facts of which we have become assured. Now *that* we *can* do. Let the specialists work out the ends they have in view, and do it well. Let it be for us to try, as far as in us lies, to add up their conclusions, and see what the specialists have done, whether they be of our own circle, or belonging to other Societies.

Former Committees of the Association have by no means been negligent in urging the Members to exert themselves to bring forward *their own* remarks, both on things within their own field of observation, and on things thought of and written about by others. Though urging the Members on, and endeavouring to indicate the most advantageous methods of increasing the usefulness and popularity of the Association, yet the successive Committees have wisely left much to individual energy and planning, knowing that

[*] The Quekett Microscopical Club followed our example in forming itself a junior Society for a field of research in which masters already existed. That well established Society courteously lends us lamps at our soirées.

the institution was not to be too parentally nursed up, nor stiffly regulated.

The Committee of the time remark that the papers read in 1 have mostly emanated from the London Members; and appea the Country Members for notes and memoranda of the works the miner, quarryman, and navvy, in their localities. "Y Committee have frequently been struck with the fact, that it is no means the longest or most elaborate Papers which elicit best discussions. A few simple observations, either in themsel new, or calculated to throw new light on the labours of form observers, or to controvert or to sustain the theories on wh Geologists and Naturalists are at present divided, will often ens a highly interesting discussion, and stimulate the defenders opponents of those theories to extend the field of their enquiri and multiply their experiments and observations, to the benefit their compeers and to the extension of scientific truth."

In the Annual Report for 1866 (printed in 1867) the Committe state that the appeals to *Country Members* for papers an specimens have not been successful. More *communicating* Membe are wanted. It is not expected, they say, that papers should b "entirely new"; and, if they convey information on the alliec sciences, they will be also welcome. "We meet (they add) foı mutual instruction : not solely to discover new truths, but to study well, and to mutually assist each other in studying, facts already known."

In 1867 there were 229 Members on the list, and several good papers had been read (as stated in the Annual Report for tha year); but they had been communicated by "ready friends" i London, and had not come from "the many Members." Agai the Committee ask for Papers affording "materials for study an information on the various fields which sub-divide the vast territor of Modern Geology."

Many of the foregoing statements and requests of former Com mittees are not out of place now-a-days. The excellent and wel worked-out papers with which we are often favoured are ver welcome, and we are grateful for them ; but we want more of th shorter bits of information about local Geology, and stirrin *résumés* of known facts.

As regards the practical value of Discussions carried on afte

the Papers have been read, doubtless we fully agree with what was found to hold good even in the first year of the Association, as shewn by the Report for 1859 (" Proceedings," vol i., p. 26, 1860), which states that in such Discussions " various opinions were given and facts noted, useful alike to the Student and the Amateur."

In 1864 the Discussions sometimes occupied more than one evening, being full of interest; and the Report for that year stated that, as a society for mutual instruction, " its discussions show that it is enlisting the sympathies and energies of precisely the class of students which it has sought to enlist in its ranks."

In the Report for 1865, the Committee stated that " more contributors of papers were required,"—a want, we know, which has frequently been felt, and has not yet disappeared; and that " more papers on palæontology " were desirable. But in this last case, descriptions of fossils are useless without figures, and these are usually too expensive for our publications. What we have at times been able to produce have been partly or wholly due to the liberality of Members.

In one respect it is, perhaps, well that we have not been much engaged in the publication of new species of organic remains, for not only are illustrations expensive, but the claims for priority are often made discordant by want of exact dates on the periodicals containing the descriptions, and our " Proceedings " very rarely bear a date coinciding with the month of their publication.

I. 2 *and* 3.—*Exhibition and Exchange of Specimens.*

1. The *Exhibition* of rare and interesting specimens of rocks, minerals, and fossils has always been readily effected among us; and has been the source of much pleasure and instruction, whether at Ordinary Meetings or at Conversazioni. There is no doubt, however, that these good results could be greatly enlarged by greater earnestness of workers in bringing or sending more and more specimens for exhibition, and if a portion of each meeting-evening, or some extra evenings, were specially devoted to this object.

2. The *Exchange*, however, of specimens has not been carried out satisfactorily, either among Members meeting in Town, or others residing at distances apart. Indeed the later editions of the Rules of the Association omit to mention it as an object in view.

At the meeting of the General Committee on February 8th,

1859, the Exchange Committee brought up a Report submitting a form of Register to be prepared for the record of particulars in reference to Exchanges among the Members.

I do not know if this Register has been preserved, or even if it were ever in use, except that in a Notice-paper, dated September 12th, 1859, the following paragraph occurs:—

"The Rooms [at No. 5, Cavendish Square] will be open for the use of Members on the evening of the *third* Monday of each month, between the hours of seven and nine o'clock, at which period the Register of Members desirous of exchanging specimens will be placed on the table."

In the First Annual Report, dated January 2, 1860 ("Proceedings," vol. i., p. 26), it is remarked that: "The Exchange of Specimens proceeds somewhat more slowly [than the formation of the Collection]; but already several boxes have been forwarded to the Association; and, as soon as a few more arrive, the Committee hope to be able to distribute the contents among the corresponding Members."

In the "Proceedings," vol. i., pp. 47, 48, printed in 1860, there is a request that "those Members who are desirous of exchanging fossils will inform the Secretary from what strata they can supply specimens, and from what formation they would wish for others in return. The Secretary will then, as soon as possible, endeavour to place the Members desiring to exchange in communication with one another."

On December 2, 1861, our fellow-member Mr. A. Bott addressed the meeeting on this subject, and urged "upon Members who had duplicates to share the advantage of Exchange."

His remarks were printed ("Proceed.," vol. i., pp. 195, 196) as follows:—

On the Exchange of Fossils among Members. By A. Bott, Esq., A.A.

"Mr. Bott stated, that having found the difficulty of getting Members to exchange specimens, and having received letters from a Country Member complaining of the same, he thought it might not be out of place, at the beginning of the Session, to say a few words on this subject. The Association would remember it was part of their original prospectus, that the object of the Association was, amongst other things, 'to facilitate the exchange of fossils among the members;' and again, it was proposed even 'to form

a Committee to communicate with Members as to the Exchange of Fossils, and the supply of specimens for the Museum; ' so that the Association gave every facility in its power for carrying out this part of its programme.

"He believed that most Members who were collectors were possessed of duplicate specimens of many of these fossils; and yet, though they had the power, though they had the services of the Association, one of the objects of which is to facilitate the Exchange of Specimens, and though they had the fossils at their command, hardly any of them, in fact, made such exchanges. He believed the only reason was, that different people put such a very different value on the same specimens, each imagining his fossils to be more valuable than those of another person.

"He would urge upon Members not to be too particular as to the money value of the fossils they received in exchange for what they sent, and reminded them, at all events, they could obtain fossils which they did not possess before, which was the great object of exchange. He himself had acted with advantage on the plan of trusting entirely to his correspondent; having effected a satisfactory exchange of fossils with another Member who, having heard through the Association that he wished to exchange, wrote to ask for some fossils from his (the author's) district, promising to send fossils from his own district in return. This was done, and the result was satisfactory to both parties.

"He would, therefore, urge upon those members who had duplicates to share the advantage of exchange."

An extra meeting was to be held on June 16th, 1862, for the Members to consult and use the Library and Cabinet. The notice-paper of June 2nd stated that, "It has been suggested that the Meeting would be a suitable opportunity for endeavouring to carry out two of the objects contemplated in the original prospectus of the Association, viz., the Exchange of Fossils among the Members, and the Rectification of doubtfully named specimens." Messrs. J. Pickering and G. E. Roberts, two earnest, but now long lost Members and friends, had undertaken to help in these arrangements.

The system of Exchange, however, has not succeeded, owing, probably, to the great amount of administrative trouble involved in it. In the Annual Report for 1865 (published in 1866), page 3, we read:—

"Your Committee have in previous Annual Reports asked suggestions and recommendations in reference to the Exchange Specimens. The subject is by no means devoid of difficulty ; t they are anxious, by constantly keeping it before the Associati to arrive at last at some practical solution." We see, therefo that, though the Laws of 1864 are silent on this point, it is cl that the Committee did not lose sight of this proposed object.

Thus, one of the proposed objects of the Society originally the Exchange of Specimens between Members, with t intention of both completing private and local collections, a furnishing fresh or different specimens for comparison and instru tion. So far this has not been productive of tangible result chiefly, it seems, because of there being no organization after whereby the wants of individuals can be expressed. It is ve evident that such a system of exchange might be productive of mo beneficial results. Students could learn to compare different speci and genera, and thus learn more. They might be led to exten their researches into those species or genera of which thei localities gave but a few samples. It is impossible to see how fa geological knowledge might not be furthered by increasing the number of laborious earnest workers ; and by mutual comparison of their collections these might learn how much more there was to be looked for, and in what direction their research might usefully be directed. For example, a person living in a Chalk district might be conversant with the commoner Chalk fossils ; but, until he had had the means of understanding from others that, besides the few common sorts—to him the only unmistakable relics of old time—there were other forms, of even wider interest, though less readily observed, as for instance as Foraminifera and other delicate and beautiful, though to some eyes obscure, forms of ancient life, he would not be capable of doing all the good he was willing to do by his local work.

Exchange, therefore, might be not merely instructive—in improving and extending the area of personal knowledge—not merely interesting as the means of bringing together fellow-students in the same line of thought, but of the highest advantage in directing the student's energies into wider ranges of thought and of research, of which, but for the specimens he had received in exchange, he would have had but a faint of idea.

Exchange, then, of specimens is but an extension of exchange

of thought, reduced to tangible facts. If, therefore, the concluding pages of the "Proceedings" contained an "exchange column,"—statements of what some wanted and what others had to give, the usefulness of the Society, as a means of extending the general knowledge of the world, would indubitably be increased.

The actual exchange could be carried out at the Meetings by agreement; for the cost of transmission by post or otherwise might be needlessly heavy. If such a system of exchange could be enlarged, it might have the very great benefit of increasing the personal knowledge of the Members, with advantage to all.

There is, I believe, an "Exchange Society" among Microscopists, but their specimens and slides go easily by post, our wares are usually too heavy for that mode of conveyance.

But, after all, there is another aspect to the question. It is unnecessary to exchange after all. Exchange may mean exchange of value in its hardest sense. Yet to one person a common Echinoderm might be (however intrinsically worthless) of real value if he did not happen to possess it. So that for exchange the term *interchange* might be adopted, and even extended into giving.

I. 4 and 5.—The interchange of geological news, and personal communications of interesting facts as to the search for and collecting of specimens, the outcome of Excursions made, and the aim and hope of intentions yet unfulfilled, form subject-matter for conversation and gossip at Evening Meetings, whether ordinary or more generally open to the friends of Members.

Conversazioni.

1863. It was proposed to hold a soirée in March of this year. (Notice-paper of January 5th, 1863.)

1864?

1865. January 5th, a soirée was attended by 100 Members and friends ("Proceed." vol. i, p. 415); and another was very successful in this year. (See Annual Report for 1865, p. 3.)

1866. There was to be a Conversazione on Nov. 6th.

1867—73?

There were no soirées between 1874 and 1877; but at the Annual Meeting in February, 1877, an exhibition of objects of interest was held after the General Meeting; and this kind of soirée has been continued since.

These methods of intercommunication aid much in the dissemination of scientific knowledge, unless a stiff formality, a want of earnestness, or the expectation of mere sensational papers interferes.

So also the *printing of papers* necessarily distributes discoveries and useful applications, besides fixing in print, for future reference, good facts and theories in Geology and the Associated Sciences. We have alluded to the "Proceedings" and the "Separate Memoirs," but the "Notice-papers" issued in connection with each *Excursion* are of more value than at first glance they appear to be. Even the earlier Notices (not always relating to excursions) are useful, and often the sole witness of what the Association has done or tried to do; and those of later date are enriched with good sections and full notes of the Geological Structure of places to be visited. It is very much to be regretted that we have no perfect series of these casual, but noteworthy and useful papers. Contributions of any such to our Library are highly desirable, not only as illustrative of the history of the Association, but as containing information often worth being referred to. It is inconvenient that, in size and shape, these papers have not been uniform; and it is a pity that they are not always printed on good paper, strong enough to stand the wear and tear of a long excursion.

In a Notice-paper dated September 12th, 1859, two "sets of printed Quarterly Papers" are referred to as having been distributed to the Members. Of these papers, as yet, I have been able to get no clear notion. One short Report* of the intention and rules of the young Society was issued under date of March 8th, 1859, consisting of an "Extract from Original Prospectus," and Rules as to Membership.

I have seen also three other Notice-papers, which may have been "Quarterly Reports," dated respectively May, 1861; February, 1862; and January 5th, 1863; and one without date, but probably printed late in 1867, or early in 1868. As these unpaged, occasional Notice-papers have not commonly been preserved (although I hope there are many more of the series than I have seen), there is added in the APPENDIX a list† of those, published in 1858-70, which have been kept by Mr. J. E. Wakefield, the Rev. T. Wiltshire, Prof. Tennant, Mr. J. Hopkinson, Mr. B. B.

* Lent to me by Mr. Wakefield.
† See Appendix I.

Woodward, and myself, as well as those in the Geological Society's Library. Others,* of later date, have been communicated by Messrs. Lobley and Hopkinson. It is hoped that friends will enable us to complete the set for the Library of the Association. Of those "Annual Reports," also, which were issued separately, there is a great want.

In spite of the earnest and conscientious efforts of the Committee and Officers, the affairs of the Association were not flourishing in 1870. The appended statistical Table shows how few Members were annually elected for 1863 to 1870, inclusive.

THE GEOLOGISTS' ASSOCIATION.

(Founded December 17th, 1858.)

Year.	No. of Members Elected.	No. of Papers Read.	No. of Excursions.	No. of Visits to Museums.
1859	164	10	—	—
1860	31	12	3	1 (Maidstone)
1861	57	28	3	1 (Oxford)
1862	60	14	4	3
1863	16	17	4	7
1864	9	11	5	?†
1865	15	12	3	?†
1866	11	11	9	?†
1867	6	9	3	1 † (Paris Exhibition)
1868	7	8	4	?†
1869	10	11	7	1 † (Oxford)
1870	7	12	11	4
1871	59	13	8	12
1872	46	17	10	8
1873	57	11	9	14
1874	49	11	8	7
1875	48	12	7	5
1876	52	14	9	6
1877	49	10	8	11
1878	32	12	5	4
1879	27	10	13	8
1880	49	9	9	8

* A friend tells me in correspondence that a chief object in keeping the occasional notices and other papers of the Association, especially the Notices of Excursions, has been that he might refer to any place that he had visited on such occasions, and thus supply dates for labelling specimens which he had collected; and, in some cases, he finds the date itself to be of use in recovering the right locality for a fossil.

† There may have been visits to the Museums in London during these years, but no notice of their occurrence has been met with.

This interesting Table of the Statistics of the Association has been compiled partly by Mr. J. Logan Lobley, and partly by Mr. B. B. Woodward, with corrections up to the present date. In 1871 we see, there was a sudden rise in the number of elections, fairly kept up afterwards until the last two years (1878-9) of "bad times" and general depression [1880 has been added while *in press*].

The personal exertions of some of the newer Members, who had considerable administrative ability as well as enthusiasm, caused a general stirring at, and indeed before that time in the society; for these, urging the desertion of some narrow and old-fashioned ways, insisted on a greater liberality towards the Members at large and the Country Members in particular. Hence there was ultimately considerable modification of procedure in printing and supplying the "Proceedings" regularly every quarter, free of expense, and in the regular issue of a Circular preceding the Monthly Meeting to all Members, and Notices with information relative to Excursions about to be taken. We must note that these kinds of publications had always been prepared and issued, as far as circumstances and means had allowed under the old system, as indeed the List of Publications* in the Appendix shows clearly, though perhaps not quite completely. But, aiming at extreme economy, the authorities had not attained the good result of satisfying the expectations of subscribing Members in Town and Country. Nor could the existing Committee be persuaded to enter fully on the new method, until, by the introduction of the rule (common elsewhere), that some of the councilmen longest at the board should leave each year, new men were amalgamated into it. Thus, with some alteration of the rules,† and a new policy of boldly applying the funds to the issue of publications and the increase of the Library, new Members being rapidly enrolled, increased receipts were the result. Doubtless the useful Library was an important element of vitality in the society, and the germ, as it were, of renewed life and vigour, especially when (in 1873) some of the funds were liberated for the purchase of books.

There were also endeavours to plan the Excursions more systematically, making them more frequent and regular, and for the most part offering greater attractions than formerly.

* See Appendix I.

† For the new rules about Committee-men retiring in rotation, see Law xv, as published in the "Proceedings," vol. iv, p. 203, January 1875.

About this time there was a reaction against an impolitic paragraph in the Notice-paper of June 14th, 1870, limiting the privilege of joining an Excursion to those who gave notice of their intention of doing so. This parental strictness, interfering with the freewill and convenience of willing Members, not being approved of, led to discussion and alterations in the management.

The occasional printing of Memoirs in full,* and the rare issue of abstracts of Papers and Reports of Excursions, and the somewhat scanty Annual Reports, between 1865 and 1870, supplemented by a failure in getting the Proceedings published regularly in the "Geological Repertory" in 1866†, had been but poor inducements for new Members to join the Association.

The revival of printed "Proceedings" in 1871 coincides with the marked increase in the number of Members (59 being elected in that year, and only seven the year before), and therefore with the improved finance; also with the increased energy among the Officers and Members which brought about a "reform," almost a renewal, of the Association. The new Honorary Secretary and Editor (Mr. Lobley) in 1871 made an Index for the eleven Nos. of the "Proceedings,"‡ vol. i, previously issued for 1859-65, and commenced the second volume with the April number for that year, in the summer of 1871, under the auspices of the new *régime*. And here it will be appropriate to state that among those who took a prominent part in thus restoring the society by improving its *status*, and enlarging and advancing its interests, I have heard the names of Mr. J. L. Lobley‖ and Mr. J. Hopkinson specially men-

* See the List of these papers above, at p. 20.

† The "Proceedings" were to have been published in the "Geol. and Nat. Hist. Repertory" once a month, and three numbers issued quarterly; and with additional postage the monthly numbers were to have been had. Only a few abstracts and papers were printed in the "Repertory," and remain imperfect. (See above, page 19.)

‡ See above, page 19, *note*.

‖ The high estimation with which Mr. Lobley's services as Secretary were regarded is shown by the subjoined extract from the Annual Report for 1873, "Proceed. Geol. Assoc." vol. iii, p. 348:—"It is with feelings of the sincerest regret that your Committee have to announce the resignation of your Honorary Secretary, J. Logan Lobley, Esq., F.G.S., who, during a period of three years, has devoted himself most indefatigably to the promotion of the best interests of the Association. A review of the progress of the Society under Mr. Lobley's auspices as Secretary sufficiently attests the advantages it has derived from his great energy, his uniform courtesy and kindness, and the zeal and industry he has shown in promoting its success on every occasion. He has, however, generously consented to give us his continued aid and assistance as Editor of the 'Proceedings.'"

tioned. The names of the other energetic reformers are published with the foregoing in the Lists of Officers and Committees of the period.

Reverting from this digression to the "Proceedings" themselves, I have to suggest (1), that the date of publication, as well as the relative date of the contents, should be printed on the covers; and (2), that a few pages of each number should be used (if practicable) for Notes and Queries, *Desiderata*, Notices of Exchange, and such like *Miscellanea*; and that this proposal should be taken into consideration, and be a subject for suggestion, by the Members at large.

II. *The Library.*—The Library was begun with the foundation of the Association. (See "Proceedings," vol. i, p. 4.) In a Notice-paper dated June 6, 1862, it is stated that an Extra Meeting was to be held on June 16th, when no paper was to be read, but the Library and the Cabinet of Specimens were to be open for exchange of the books on loan, and for the study of the fossils. Some Members had promised to bring microscopical objects for examination.

From that time onward nothing but quiet congratulation on the possession of a Library, and hopes that it will be well supported and enlarged, occur on this subject in the Reports, which have always to record the willing assistance of successive Honorary Librarians in taking charge of the Books and dispensing them to the Members on the Evenings of Meeting. Pecuniary assistance, however, to the Library has always been limited, and before 1868 (excepting an occasional small grant) was at a minimum. The Catalogue of the Books in our Library was first printed in the Annual Report for 1862 ("Proceedings," vol. i, p. 310); and was inserted in the successive Annual Reports until 1876.

In February, 1879, a very careful and well printed Catalogue was published, and a Supplement of *Addenda et Corrigenda* was issued in 1880. This Catalogue had been prepared by our enthusiastic Librarian, Mr. B. B. Woodward; and from the Preface written by him, but not published, I take the following extract, which expresses what I wish to say on the subject:—

"'The formation of a Library,' or 'the gathering of sound geological books,' for the purpose of reference and study, was one of the 'objects' for which the Geologists' Association was estab-

lished, and one which was immediately acted on, for at the second Ordinary Meeting (March 8, 1859) this useful undertaking was fairly started, the first Donations being recorded in the Proceedings of the evening.

"Since that date, with some few exceptions at the beginning, Donations have continued to come in at each Meeting in steady and ever-increasing numbers.

"Voluntary contributions formed for some time the sole support of the infant Library, until at the Annual Meeting, held January 7, 1861, the Committee were enabled to recommend that the sum of £5 should be expended in the purchase of 'good geological works.' The Report being adopted, this recommendation was carried into effect; and a list of the works thus obtained is appended to the Proceedings of that date. Further sums were afterwards, from time to time, invested in like manner, notably in 1862, when the still unrivalled 'Monographs of the Palæontographical Society' were added to the collection.

"Yet a third source, whence additions to the Library have been obtained, needs to be mentioned. By instituting a system of exchange of 'Proceedings' with kindred Societies all over the country, a series of useful and valuable volumes have been gathered together at a small expense to the Association, but to the greatly enhanced worth of the Library, both as a means of reference and of acquainting the Members with the work of the various local Geologists who contribute the results of their investigations to such Societies.

"Starting with only ten, this practice has gradually spread until, at the present time, there are more than thirty Societies on the list, and fresh applications, some even from Foreign Societies of note, have been received."

On this topic I have little to add, except that we have now (I am informed by our energetic Honorary Librarian) about 1,300 works in the Library. These books are well appreciated as aids to knowledge in many ways. Our aim should be to accumulate for use as many as possible of these handy depositories of thought and facts. Our funds have not allowed of much liberality as to books. This is a pity! I merely add that our present Bookcase was bought and set up in 1872; and that a larger, or additional, case is very much wanted now.

III. *The Collection of Typical Fossils.*—In the first "Annual Report" ("Proceed.," vol. i, p. 26), January 2, 1860, the Members were told that—

"The formation of a typical collection of Fossils is in progress. The work proceeds satisfactorily; and the Collection will no doubt shortly become of considerable extent, since many Members have promised to contribute specimens as soon as a proper Cabinet could be obtained, which has now been done."

By a Notice-paper, or Quarterly (?) Report, of "May, 1861," the Members learn that—

"The number of typical Fossils already accumulated is far too great for the limited amount of cabinet-room at the disposal of the Association."

In the "Annual Report of 1862" (February, 1863, "Proceed.," vol. i, p. 305), a list of the fossils presented during the year is given.

In 1865 ("Annual Report for 1864") a Sub-committee reported that "the Collection already exceeded the space available for its reception, and recommended the enlargement of cabinet room, and measures for rendering it more available to Members." It was proposed that an Extra Meeting should be held on the 24th January, 1865, to examine and compare the Fossils of the Cabinet, as well as any specimens which Members might bring or send for exhibition.

In 1866 the Report of 1865 was read, and the Cabinet of *named typical Specimens* is referred to, with its "increased accommodation;" and more specimens are asked for.

In 1867 the Committee stated, in the "Report for 1866," that they wished to see the Cabinet in a more satisfactory position, (the Association met at King's College at that time). They remarked that a "fairly typical Collection" would be "perhaps desirable for the Evening Meetings;" but there are some large National Collections available to the Members for the purposes of study; and they intimate, therefore, that the expense and trouble of a Special Museum might be avoided by the Association. They invited, however, suggestions on the subject, especially how to complete a collection useful for the Members; and they think that the Specimens should be more readily got at and *periodically studied.*

Since 1867 ("Report for 1866") the Collection and its Cabinet

have not been referred to in the "Annual Reports;" * and the Cabinet is not brought forward at the Meetings. Indeed, as we have stated above (p. 14), the formation of a typical Collection was no longer alluded to, even in the Rules printed in 1864.

Doubtless no species of mineral or of fossil can be properly determined without the comparison of typical specimens. We must go either far or near for these. There are, however, both private and national Collections open to students and workers. The new arrangements and well-considered accommodation for students at the new National Natural-History Museum, "British Museum, S.W.," at South Kensington (though awkwardly distant) will be greatly conducive to useful study and good results. Whether the limited typical collection ("fossils" only seem to have been always entertained by the Committees), so long thought of and so frequently alluded to, would now be of real value to the Members on Meeting-nights and at other occasions, and not too expensive in its preparation and preservation, they can best decide, if the subject has to be definitely determined. Probably an economic exchange of the fossils † for *books* would be productive of more good than the Collection can at present afford.

IV. *Excursions or Field-Lectures.*—I have already alluded, at p. 11, to the establishment of a system of Field-Lectures. In the "Geologist," vol. ii, p. 329, August, 1859, there were suggestions for the Association to have Excursions, with a reminder that early Members had desired there should be field-meetings, as being of as much use (especially to Country Members) as indoor readings and discussions. It was also suggested that an annual field-meeting should be held, with readings, as with the British Association, or "something of this kind," by aid of the Excursion-trains; and thus Country Members and their city brethren could more easily meet and interchange thoughts and courtesies. The letter was signed "PROVINCIAL GEOLOGIST."

At page 368 of the same volume of the "Geologist" it appears that the Rev. T. Wiltshire, then President of the Association, was deputed to state that during next year [1860] the Com-

* In a Notice-paper of 1871, copied from one of 1867, the "Typical Collection" is still referred to as one of the original objects of the Association.

† The Collection is at present in the Library of the University College, where the Association has the privilege of holding its Meetings; and it is stored away in a part of the old book-case of the Association.

mittee of the Association would "invite the Members to a geological ramble, and to spend a summer's day both pleasantly and profitably;" and he said truly that "a lecture given at a natural section, and on the fossils *in situ*, is far more valuable and instructive than one illustrated by the most expensive diagrams."

The first notice of an Excursion of Members we meet with is of that to Folkestone, April 9, 1860. Maidstone, also, and Charlton are mentioned in the Report of January 7, 1861, as having been visited in 1860. Redhill and Reigate, in April, Oxford, in May, and the Isle of Sheppey in August, 1860, were next visited.

The Annual Report for 1861, given in January, 1862 ("Proceed.," vol. i, p. 200), states that "The plan of conducting occasional Excursions to places of geological interest, which was organised in 1860, has proved a complete success."

Hastings (50 members), Cambridge, and Lewes were soon afterwards visited; and the Brighton Museum, the Main-Drainage Works, and the International Exhibition, drew attention in 1862.

In 1863 the Committee seem to have had good reason to report that "the Excursions to places of geological interest have proved as successful as in former years. On all these occasions the local geologists, and others feeling an interest in Geology, have stepped forward to assist; and on more than one occasion have hospitably entertained the Members of the Association who were present."

In the Report for 1864 Country Members were asked to aid with their local knowledge in the arrangement of Excursions. In the Report for 1865 the Committee state that they feel it to be their duty "to point out the wide field open to the exercise of your Members' energies, and the particular direction which might with most advantage be given to them." With this view, they "propose to give them [the Excursions] a somewhat more formal organization," so that absent Members "may profit by the results of their more fortunate colleagues."

In the Annual Report for 1866 it was intimated that Excursions are necessary for practical and good knowledge, besides the cabinet and lecture-room, and that good Excursions require—1. Good planning; 2. Good leaders; 3. Good reporting; also that it is a pity to lose the results of Excursions for want of the last.

In a Notice-paper of July 11th, 1866, it was advertised that, should twelve names be received before August 1st, a two-days

Excursion would be made to Matlock. This seems to be the first indication of the *Long Excursions.*

In 1867 M. de Verneuil, President of the Geological Society of France, invited the Members of the Geological Association to take part in the Meeting of the Geologists at Paris; also in the Excursions and the visit to the International Exhibition that they then organized for themselves and friends.

Some Members having visited the Paris Exhibition (International) in 1867 (by invitation), and having been impressed with the desirability of advancing Technical Education, and feeling assured that the practical learning of Geology in the field is of this kind, the Committee urge upon the Members the importance of assisting at the Field-Lectures (some of which had of late been poorly attended), both by more constant attendance and by suggestions as to fixing upon the best places, the best plans, and the best times for their Excursions; also for their more active co-operation in securing full Reports of these Excursions, and in securing an unbroken supply of useful Papers for reading at the Ordinary Meetings.

The next Annual Report speaks of the satisfactory increase and development of Excursions, and of the good number and quality of the Papers printed and circulated among the Members.

In the "Annual Report for 1869" (published in 1870), the Committee urge "the importance to geological students of verifying in the field the statements and inferences they find in books." The many printed Reports of the Excursions demonstrate, they say, "the truth and value of their former appeals."

We append * a List of Excursions made by the Association, and need not follow further the history of the Excursions, which are so well appreciated and sometimes so well attended by the Members. Without this kind of work many of us would know geology merely as readers; and out-door work greatly enlarges our mental grasp.

The geological formations inspected or examined at the Excursions have been for several years tabulated in the Annual Reports, with the lists of the Excursions, Directors, and local entertainers.

Excursions.—It may be objected by some that our Excursions lead us too often to the same spot. It cannot be too definitely

* See Appendix II.

pointed out that the true study of Science does not consist in the pursuit of mere novelties. Many of those whose names are broadest writ on the scroll containing the names of the great seekers after Truth are the men who have given their lives to the study of one branch of knowledge. They have been specialists, and have spent a life-time in studying one set of things; with the feeling, too, at the end, that after all they have but been gathering shells and pebbles by the side of the great ocean of "What there is to know." If these great pioneers of knowledge have thought it wise and good and useful to spend their lives in the steadfast examination of one group of facts, one class of events, one set of phenomena, surely we, who, compared with them, have but dilettanti aims, can at least find useful work in the occasional repetition of one line of thought, whether studying rocks in the field, or writing papers at home.

It is but a weak saying:—"Change is necessary for work." What if we do visit, not twice or thrice, but twenty or thirty times, the same set of strata, the same geological formation? Do we not, each time we visit a quarry, learn that we never see the same thing, never exactly the same set of rocks and minerals, never the same kind of fossils even, that is, under the same condition of deposition or of preservation? No earnest geologist sees in a revisited section of strata, even in a limited area, the same set of facts exactly: there is new evidence of a change of current here, a change of conditions there, an alteration in the local form of life elsewhere. All the same as before to the careless eye—but how great, and wonderful sometimes, a variation to the mind of the thoughtful man! Take a common gravel-pit for instance. Here the "pan" is thicker and stronger; there the gravel is more subangular or coarser—here there is a pocket of quartz grains—there some loam and finer sand. Much is to be learnt, we know, from these minor changes in a hundred yards of section. And if this be true of one poor gravel-bank of an ancient sea-creek or shoaling beach, how much more so for other portions of the *same Geological Formation* seen at places many miles apart!

Chalk at Guildford and chalk in the Isle of Wight are both chalk and nothing but chalk—blank, white, and meaningless—to a mere "Tourist;" but it is not quite the same, however nearly the external appearances may approach each other. Different depths of the sea in which it was formed, varying tides and

winds, different families of organic beings, different conditions of these same families even, obtained at every different place.

The Anglo-Saxon in America is not quite the Anglo-Saxon of Great Britain; the Englishman of the West of England is not the same as the Kentish man, and yet they belong to the same race. It were as wise to say that, because we have seen the scenery of the English Lakes, it would be waste of time to see the Scotch Lakes, both being *Lake Countries*, as to say, because the Geologists' Association have seen the London-clay at Sheppey, it is unnecessary for them to see the London-clay at Reading, or to see it again and again at one or both places. Above all things it is requisite that we should avoid assuming that, having seen the fringe of Scientific Things, we should dismiss any one thing as known.

All this applies equally well to good papers which at our Meetings we may hear read on similar matters, and bearing the same titles. Even if about the same set of things, the thoughts and conclusions have filtered through other minds, and may be presented to us in a different aspect, and in a more useful form. A story may be well told by one observer, and better by another. In the well-known " Evenings at Home " two observers see the same lanes and heath-land and surrounding nature. The one has learnt nothing, yet tells his story ; the other returns with new ideas, new thoughts, and new observations. As this story is differently told by the two boys, so may it be said of all research; and thus we get the lesson—that no two pairs of eyes have quite the same way of looking at things, nor two observers quite the same way of telling them.

The methodical observer, however, seeing with enlightened eye the works of the Creator, and favoured with the intellectual power of interpreting their meaning, thereby gains for himself knowledge useful for mankind. He is blest in receiving and giving this knowledge: at the very least, he sees more and enjoys more than the uneducated man—for

> "To the cultur'd eye of Taste
> No Rock is barren, and no Wild is waste."

Local Museums and Local Finds.—It has been suggested to me by a friend that the opportunities for examining local collections during our Excursions might lead to the following line of thought.

The formation of either a General Museum, or a series of local Museums, is, perhaps, impracticable, and is frequently unnecessary. Primarily, they would rarely be complete; next, in most instances, better collections can be studied elsewhere. But it would always be unwise to check the collection and preservation of really valuable specimens. But what are valuable specimens? What is really worth keeping, on broad national, if not on private grounds? This may be answered by creating the means of authoritatively deciding what is new, rare, or abnormal. Thus if such personal collections could be inspected by Scientists, who could advise the collector as to the relative or the intrinsic worth of what he had gathered together, a great step in advance would sometimes be made. Valuable fossils would no longer be consigned to the dust-heap, nor would common or indifferent specimens find their place in, and encumber the cabinets of the curious.

If, therefore, those members who have been so fortunate as to accumulate a series of local fossils, minerals, or lithological specimens, could have the means of asking for the assistance of the more experienced fellow members, good would be done to Science, and additional interest imparted to local finds.

V. *Lectures.*—Courses of instructive Lectures were to form one of the chief features of the newly instituted Society.

Mr. S. J. Mackie's "Lectures on Palæontology" were announced to commence on October 10th, 1859. In the first Annual Report, dated January 2nd, 1860 ("Proceedings," vol. i., p. 26), we find that the design of giving class-lectures had been carried out under the superintendence of Mr. Mackie, in two separate courses, of six lectures each. This part of the Association's programme does not appear to have been carried further, however useful it might be made, among some, at least, of the Members, who might wish for a systematic and continued treatment of some branches of their favourite subject under circumstances which would admit of the colloquial method specially adapted for Mutual Instruction.

VI. *Local Secretaries and Committees.—Honorary Local Secretaries* were appointed in the early days of the Association, after the system of the Palæontographical Society, to advance the interest of the Association in the Counties.

In the Notice-paper of March 8th, 1859, the Officers of the Association are the Rev. T. Wiltshire, President; Messrs. J. E. Wakefield and W. H. T. Allen, Hon. Secretaries; Messrs. John

Brown,* of Stanway, Essex; George Grant Francis, of Swansea, Glamorganshire; and Edward Wood, of Richmond, Yorkshire, were the Honorary Local Secretaries. Mr. Pulozki was the Honorary Foreign Secretary; and Mr. Hislop was Treasurer.

In 1862 the Rev. L. H. Mordacque, Parsonage, Haslingden, near Manchester; Dr. E. P. Wilkins, F.G.S., Newport, Isle of Wight; and Mr. E. Wood, F.G.S., Richmond, Yorkshire, were the Hon. Local Secretaries.

Mr. Hyde Clarke (see page 17) and others, had in view at this time (1859) "The cultivation of beneficial relations with the Country Field-clubs and Societies." This was again urged in the "Annual Report for 1869"; and has been carried out to some extent.† Possibly, however, following the example of the "Mineralogical Society of Great Britain and Ireland," subsidiary colonies of associated Geologists might flourish usefully under Local Secretaries, in communication with the mother Society.

VII. *Special Objects and Desiderata.*—It was suggested in 1870, in the "Annual Report for 1869," wherein the Committee had the pleasure of congratulating the Association on the improvement in the number and quality of both the Excursions and communicated Papers of 1869, that the Association should take into consideration the possibility of conjoint action in the preparation of a Hand-book of Metropolitan Geology, since the form in which the invaluable results of the labours of the National Geological Survey "is not generally available for the purposes of the student, while the scale and range of a National Survey necessarily prohibits the inclusion of many points of detail which are highly interesting to local observers." Nor, may we add, does the Geological Society admit of *general* description and *repetition* of

* Our old friend, Mr. John Brown, F.G.S., of Stanway, died in the course of this year (1859). He had studied Geology, and learnt its value, in his practical business with building and paving stones; and he never lost an opportunity of gathering information, or of imparting it to others, especially in his own neighbourhood about Copford, Essex. Here, at Cromer, on the Coast, and elsewhere, the Post-tertiary deposits received his special attention, as his collections, now chiefly in the British Museum, bear witness. At the last his love of the Science, and his consideration for Geologists were shewn by Bequests of Money to the Geological Society of London and the Geologists' Association. His Legacy of £100 is referred to in the "Proceedings," 1859, vol. i., p. 27; and at p. 200 (1861) it was intimated that the Library would shortly be benefited by the expenditure of £5, which the Committee were thus enabled to afford out of the funds, beyond the £8 spent on Books in 1860.

† Members of local Societies have often joined the Geol. Assoc. in Excursions.

detail. As this work has not yet been taken in hand in the method proposed, the subject is still open for consideration.

With respect to more detailed work in the London district, the Association is more to be praised than blamed. It has not allowed much to pass unobserved in the artificial openings and sections in and near London. Thanks to the energy of many of our Members, seconded by the considerate courtesy of the members of the Metropolitan Board of Works, who have always been among our friends and supporters, all the great excavations in the Metropolis have been noted. The neighbouring railway sections also have been carefully watched.

In the "Proceedings," vol. i., p. 351, in a paper read Nov. 3rd. 1863, Mr. Caleb Evans recommends the "examination of Geological details of the various undertakings" carried on "in the neighbourhood of London, as a work for which the Geologists' Association is well fitted." And certainly he himself and some others have done it well.

In the Report for 1865, the Committee, finding that the Country Members do not supply many papers and observations, propose to draw up a list of *Desiderata* for circulation, "pointing out special topics to which their attention might with benefit be directed."

This was praiseworthy, but probably not of much use. The late J. W. Salter, in the "Geologist," vol. i., pp. 301-3, and Hyde Clarke in the "Geologist," vol. ii., p. 169 (see also above p. 10), mentioned many geological things of interest for examination; and the late Mr. G. E. Roberts supplied the Association with a few pages of "Notes and Queries" in 1864, which were printed and distributed. It was proposed to continue them periodically.

In the 1865 Report, however, the Committee "regret that the circulation of Mr. Roberts' suggestions for registering observations and experiments have not borne more abundant fruits. They believe that the resources of the Members of the Association are amply sufficient to maintain a journal of this kind, and they appeal, therefore, for their aid in developing so good an idea."

The idea still waits to germinate and fructify.

The production of accurate photographic representations of sections and organic bodies has at times been an object of interest to the Members of the Association. (See "Proceed.," vol. i., p. 64, &c.) If the same desire exists of using the art geologically, and of mutually combining to get good and useful results, some

Members interested in the matter might join in doing their best to carry out the project.

VIII. *Lady Members of the Association.*—Rule III. "Ladies shall be eligible for election as Members of the Assocation." Not without reason was this Law regarded as a very important element in the constitution of the new Society in 1858. Women, as well as men, can be Geologists, as far as their strength for travel, and opportunities among domestic affairs, will allow.

In one aspect particularly it is well that women should know Geology, for thereby they are enabled to sympathise with, and to understand man's work in this interesting and not always easy line of Scientific work and thought. One link the stronger between educated man and woman!

Doubtless for many ladies it is hard to tramp about on Geological Excursions over rough roads, hillsides, hedges, ditches, and sea-side rocks and shingle. Let special Excursion-lines be planned, so that we may have the pleasure and advantage of female society. The first notice of the presence of ladies at Excursions was in 1861. Few appear to have attended the field-lectures at any time, until June 23rd, 1870. Since then they have often graced the outings with their presence.

In the Meetings of the Association the female element is an adornment, and a social pleasure. As in Universities (now-a-days) and Colleges, as in the British Association, and Archæological and Social-Science Congresses, so in our Association, how greatly would the scientific meetings and outings lose if the ladies were absent! Some, perhaps, might dare to think that the Universities and Scientific Societies are natural masculinities, and require no feminines, except in the dead and foreign languages, and with some naturally monœcious things! Short-sighted persons! All nature shows that the womanly type (of various degrees) is necessary for both individuals and societies. The type with which we are favoured is a high type, and we respectfully make much of it. Ladies can not only equal Wranglers, as the mathematical lady-graduate of Girton College has recently shown, but ladies can excellently well help geologists, and be geologists themselves. Who requires to be reminded of the intellectual powers and persistent energy of the well-educated woman? We can readily speak of the Lady Members of the Association as types of good thinking women, able and willing to know about the Earth *as the Earth*, and to learn from other persons, as well as from books,

what has been gathered of such knowledge, and what is being thought of old and new notions thereon. The pleasant influence of ladies at the Meetings is universally felt. Women can attend Geological Meetings without hurt to their sensitiveness. Geology, though one of the most comprehensive, is one of the most plain of Sciences.

IX. *Conclusion.*—It seems worth while to look up the details of the history of this Association for several reasons; but whatever they may be, it is at present sufficient to say that, having been praised by a competent Geologist before a large assembly of Foreign Geologists, we must take it for granted that our rise and progress have been reasonable and successful, and therefore worth noting. Mr. T. Davidson, lately our esteemed Delegate to the Geological Society of France,* to convey congratulations on their Fiftieth year of Existence, found it in his heart to say—"The Geologists' Association of London has also rendered very great service to the science. Founded twenty-one years ago by a number of young men desirous of learning Geology economically by mutual help, and by discussion among themselves of geological questions at the very places where sections and exposures are seen, this Society consists of excellent geologists; and many of their works would be of credit to geologists of greater pretensions."†

We fully appreciate this praise; and we know that those who have been here before us have worked hard and willingly that the Association should deserve it.

Lastly, let me say that now-a-days the value of Science is recognised by Society at large, both in some form or other in most systems of Education, and more largely and practically in the pursuits and business of active life. To follow out researches in Natural Science is a wholesome exercise for mind and body; and the results, though not always immediately effective of good in inventions and applications, are invaluable links in the great chain of known facts, uniting the intelligences of past ages with the present, and the mind-work of many widely-separated peoples. Ultimately these results are welcomed as bringing new advantages, new riches, new enlightenments, and new comforts as additions to the public good.

Geological study fulfils both of these expectations. It benefits

* See the Appendix, III.

† "Quart. Journ. Geol. Soc.," No. 143, p. 97.

the individual, while working in the open air, with fresh scenery and healthful exercise; and, while working at home, with good and useful thoughts, and with the pleasures of discovery. It benefits Society by teaching the avoidance of error in working on and in the earth, by directing and facilitating such work, and by cultivating a good, free, discriminating, and conscientious turn of mind. It helps and improves especially the Architect, Engineer, Miner, Traveller, and Officers of the Army and Navy.

The Geological Society, established long ago, in the interest of our science, was fitted for advanced students; and, high in its monetary requirements, as in its scientific treatment of Geology, was not found available in 1858 for the very many would-be students of our fascinating and useful branch of knowledge. For they wished to enter on the study by personal intercourse with others, mutually interested in the science, rather than by the dry road of books alone.

This much-felt want of some common means of intercommunication among willing learners, who shrank from ranking themselves among the illustrious masters of the Science, induced some 120 of the early Members of our Association to modestly seek *mutual* help as students; and they organised themselves into this healthy and useful body of geologists, so many of whom I have the honour of addressing on this occasion. They proposed, as we have mentioned above:—1, to hold regular meetings for reading and discussing Papers; 2, to form a Museum of typical specimens; 3, to afford facilities for collecting and exchanging specimens; 4, to afford facilities for exhibiting, comparing, and naming specimens; 5, to communicate information as to the best places and methods of search, and to visit geological localities; 6, to establish a Library of reference; and 7, to have short courses of Lectures on appropriate subjects.

The first General Meeting was held on December 17th, 1858, to organise this new Society for the promotion of the study of Geology and its allied Sciences.

The first Ordinary Meeting of the Association was held on January 11th, 1859. Nearly 200 persons were present; and the late Mr. Toulmin Smith, in his Address, urged the necessity for union and mutual help in collecting "True Facts," getting rid of false notions, and promulgating real Geological knowledge.

How far the hopes of youth and the aspirations of adolescence had been verified within our twenty-one years of existence last

spring, you can very well judge for yourselves. You have had full Meetings in town, and pleasant Excursions in the country. You have had the experience of energetic Collectors—the ripe knowledge of learned Philosophers—the bold theories of enthusiastic Thinkers placed freely at your disposal, often with the agreeable accompaniments of the courtesy and hospitality of friends and well-wishers.

In these gatherings, whether between walls or on hill-tops, you have mutually given and partaken of geological knowledge, as the founders hoped. In your Library you have what they only wished to have; and, though you have no great expensive Museum, all museums are open to you.

Your published Proceedings are worthy monuments of patient investigation, mutual improvement, and disseminated knowledge. The sources of such Papers as they contain, and the skill and care that put the Proceedings into shape, speak well of the constitution and practice of this Association.

With such aids to knowledge, and with such means for obtaining its good results, as you have made for yourselves or gathered around you, you have much to be pleased with—to be glad of—to be proud of—and, therefore, to be thankful for. But let us remember that, as a society of amateurs and students, we must follow the lines and precepts of our founders; and, while congratulating ourselves on good results, and giving expression to our ardent desire for the continued well-being and usefulness of the Geologists' Association, we must not forget the founders and supporters of the Society, but be warmly grateful to those who have gone as well as to those who are still with us.

APPENDIX I.

A CATALOGUE OF REPORTS, NOTICE-PAPERS, &c., ISSUED BY, OR RELATING TO, THE GEOLOGISTS' ASSOCIATION, FROM 1858 TO 1871. (PROBABLY INCOMPLETE.)

	Date.		*Description.*
1858.	December 6	...	Prospectus.
1859.	January ...	...	"Geologist," No. 13, including the Prospectus.
—	February	...	"Geologist," No. 14.
—	March 8 ...	...	Report. (First Report.)
—	? ...	...	List of Members.

	Date.		*Description.*
1859.	September 12	...	Notice paper of coming Meetings, &c.
1860.	August 2...	...	„ Excursion to Charlton.
—	October 15	...	Notice paper : Meetings.
1861.	March 28	...	„ Excursion to Reigate.
—	May 9 ...	...	„ Excursion to Oxford.
—	May ...	...	Report. (? Quarterly Report.)
1862.	February...	...	Report. (? Quarterly Report.)
—	February...	...	List of Members.
—	April 11 ...	...	Notice paper : Excursion to Hastings.
—	June 6 ...	...	„ „ Cambridge.
—	September 19	...	„ Visits to Museums, &c.
1863.	January 5	..	Report. (? Quarterly Report.)
—	June 18 ...	...	Notice paper: Excursions to Kew, Herne Bay, &c.
—	July 16 ...	...	Notice paper : Excursion to Dover, &c.
—	August 15	...	Report of Visit to Dover. (From a Newspaper.)
1864.	...	...	Annual Report for 1863, with Laws, List of Members, &c.
—	March 18...	...	Notice paper : Excursion to Sevenoaks.
—	June 12 ...	...	„ „ Bromley.
—	...	...	G. E. Roberts' "Notes and Queries." No. 1. Read June 4, 1864.
1865.	...	...	Annual Report for 1864, and Catalogue of Books.
1866.	...	...	Annual Report for 1865.
—	February...	...	Notice paper of Meetings (at King's College), and Excursions to Rochester, &c.
—	March 24...	...	Notice paper : Excursions to Charlton and Grays.
—	May 16 ...	...	Notice paper : Excursions to Cambridge and Holloway Railway-cuttings.
—	June 7 ...	...	Notice paper : Excursions to Brighton, Highgate, and Sevenoaks.
—	July 11 ...	...	Notice paper : Excursions to Finchley Road, Folkestone, &c.
—	July 28 ...	...	Notice paper : Excursion to the Isle of Thanet.
—	Autumn ...	...	„ Meetings, &c.
—	November	...	„ Conversazione at King's College on Nov. 6.
1867.	...	...	Annual Report for 1866, with List of Books, &c.
—	...	...	Report (Notice paper).
—	April 13 ...	...	Notice paper: Meetings, and Excursions to Lewes, Hunstanton, and Sheppey.
—	December 4	...	Notice paper : Meetings.
—?	Winter of 1867, or Spring of 1868		„ General (J. Cumming, Hon. Sec.).
1868.	...	...	Annual Report for 1867.

Date.			*Description.*
1868.	...	...	List of Members.
—	April 17 ...	...	Notice paper: Excursions to Lewisham (with sections), Sheppey, Grays, and Reigate.
—	June or July	...	Notice of Meeting of July 3; and Abstract of Mr. Crombie's paper on the geological distribution of British flowering plants.
—	December 24	...	Notice of Meeting of January 1, 1869.
1869.	...	...	Annual Report for 1868, List of Books, &c.
—	May 4 ...	...	Notice paper: Excursions to Oxford, Charlton, &c.
—	May 29 ...	...	Notice paper: Excursions to Guildford and Godalming; and Meeting of June 4.
—	June 15 ...	...	Notice paper: Excursion to Caterham.
—	July 29 ...	...	Notice paper: Excursions to Hunstanton, Tottenham, and Isle of Wight.
—	...	...	Reports of Excursions to Oxford, Guildford, Caterham Junction and Croydon, Hunstanton, Tottenham, and Crayford. In one pamphlet.
1870.	...	...	Annual Report for 1869, and List of Books.
—	March 15	...	Notice paper: Visits to Museums.
—	March 28	...	,, ,, ,,
—	April 12 ...	...	Notice paper: Excursions to Caterham, Grays, Lewisham, Swindon, and Erith.
—	May 24 ...	...	Notice paper: Excursions to Nutfield, Aylesbury, Herne Bay, and Hampstead.
—	June 14 ...	...	Notice paper: Excursions to Maidstone, Folkestone, and Watford.
—	June 29 ...	...	Notice paper: Meeting of July 1. (J. Cumming, Hon. Sec.)
1871?	(without date)	...	Notice paper: General. (J. L. Lobley, Hon. Sec.)

APPENDIX II.

LIST OF EXCURSIONS AND VISITS TO MUSEUMS.

EXCURSIONS.—1860.

Places.		*Dates.*		*Authorities.*
Folkestone ...	...	April 9	...	Proc. i., p. 47, 89.
Maidstone and Musenm	...	June 19	...	,, p. 63, 89.
Charlton ...	...	Aug, 13	...	,, p. 64, 89.

1861.

Redhill and Reigate	...	April 9	...	Proc. i., p. 149, 200.
Oxford and Museum	...	May 20	...	,, p. 156, 200.
Isle of Sheppey ...	...	Aug. 1	...	,, p. 166, 200.

Places.	*Dates.*	*Authorities.*
	1862.	
Hastings	April 22 ...	Proc. i., p. 248. 50 Members.
Cambridge and Museum ...	June 13 ...	„ p. 271.
Lewes	Aug. 6 ...	„ p. 274.
Old Ford (Drainage Works)	Oct. 18 ...	„ p. 277.
	1863.	
Dudley...	May 27 & 28	Proc. i., p. 334, 358.
Herne Bay and Reculver ...	June 26 ...	„ p. 339, 358. 30 Members.
Ipswich and Museum ...	July 20 ? ...	„ p. 358.
Dover	Aug. 20 ...	„ p. 358. In newspaper.
	1864.	
Sevenoaks	March 29...	Proc. i., p. 390.
Bromley...	June 18 ...	„ p. 404.
Oxford	? ...	
Folkestone	? ...	Annual Report for 1864.
Isle of Wight ... ... ("Geol. Repertory," p. 28 ?)	? ...	
	1865.	
Faringdon	? ...	
Swindon	? ...	Annual Report for 1865.
Hythe	? ...	
	1866.	
Rochester	? ...	Notice-paper, Feb. ? 1866.
Charlton	April 7 ...	
Grays	April 21 ...	
Cambridge	?	
Brighton	June 11 ...	
Holloway and Highgate Railway Cuttings	June 16 ...	Annual Report for 1866; and Notice-papers in 1866.
Sevenoaks	June 20 ...	
Midland Railway Tunnel Works, Finchley Road	June 11 ...	
Folkestone	Aug. 2 ...	
Isle of Thanet	Aug. 4 ...	
	1867.	
Lewes	April 22 ...	
Thames Embankment Works	April 27 ...	Annual Report for 1867.
Hunstanton	May 31 ...	
	1868.	
Lewisham	April 25 ?...	
Isle of Sheppey	May 4 ? ...	Notice-paper, April 17, 1868.
Grays, Essex	May 23 ? ...	
Reigate	June 20 ?...	

1869.

Places.	*Dates.*	*Authorities.*
Oxford and Museum* ...	May 17 ...	Annual Report for 1869.
Charlton	May 22 ? ...	Annual Report for 1869.
Guildford*	June 2 ...	Geol. Mag. vi, p. 331.
Caterham and Croydon* ...	June 19 ...	Annual Report for 1869.
Hunstanton*	Aug. 3 ...	Geol. Mag. vi., p. 427; and Annual Report for 1879.
Tottenham*	Aug. 7 ...	Annual Report for 1869.
Crayford	? ...	Annual Report for 1869.

1870.

Caterham and Oxtead ...	April 19 ...	Proc. ii., p. 28.
Grays	April 23 ...	„ p. 29.
Lewisham	May 7 ...	„ p. 33.
Swindon, Stroud and Mayhill	May 9-11...	„ p. 33.
Crayford and Erith ...	May 21 ...	„ p. 34.
Tilburstow Hill and Nutfield	May 28 ...	„ p. 35.
Aylesbury	June 1 ...	„ p. 36.
Herne Bay	June 6 ...	„ p. 38.
Hampstead and Mr. Caleb Evans' Collection	June 11 ...	„ p. 40; Annual Report for 1870.
Folkestone	June 18 ...	„ p. 41.
Watford...	June 23 ...	„ p. 43.

1871.

Cambridge, and Museum ...	Apr. 10 & 11	Proc. ii., p. 219.
Belvidere, and Mr Spurrel's Museum ...	April 29 ...	„ p. 229.
Oxford, and Museums ...	May 12 & 13	„ p. 243.
Grays, Essex	May 20 ...	„ p. 245.
Yeóvil, and Collections ...	May 29—June 1	„ p. 274.
Ilford and the Brady Museum	June 17 ...	„ p. 273.
Caterham and Riddlesdown	July 1 ...	„ p. 274.
Warwickshire, the Warw. N. H. Soc. Museum, and Rev. P. B. Brodie's Museum	July 10 & 11	„ p. 284.

In a Notice-paper of 1871, copied from one of 1867 or '68, both Tunbridge and Harwich are mentioned as having been visited by the Members. At p. 200, vol. i. of the "Proceedings," it was proposed to visit these places, but they do not appear in the foregoing list

1872.

Maidstone, and Museum ...	April 2 ...	Proc. iii., p. 38.

* Reports of these Excursions were printed in one 8vo. pamphlet, dated 1869.

1872.

Places.	*Dates.*	*Authorities.*
Watford and Bushey ...	April 13. ...	Proc. iii., p. 65.
Hampstead, and Mr. C. Evans' Collection	April 27 ...	„ p. 67.
Erith and Crayford ...	May 4 ...	„ p. 83.
Bath, and Museums ...	May, 20 & 21,	p. 89.
Guildford and Chilworth, and Mr. Godwin-Austen's Collection	June 1 ...	„ p. 93.
Bromley and Chiselhurst ...	June 15 ...	„ p. 114.
Hendon and Finchley; and Dr. Hicks' Collection	June 22 ...	„ p. 115.
Walton-on-the-Naze ...	July 8 ...	„ p. 122.
Ludlow and Museum, and the Longmynd ...	July 22-27...	„ p. 124; Ann. Report for 1872, p. 5.

1873.

Places.	*Dates.*	*Authorities.*
Banbury, and Mr Beesley's Museum ...	April 14 & 15	Proc. iii., p. 197.
Charlton	April 26 ...	„ p. 205.
Aylesbury	May 5 ...	„ p. 210.
Eastbourne (Collections), and St Leonards	May 23 & 24	„ p. 211.
Finchley	May 31 ...	„ p. 214.
Brighton, and Museum and private Collections	June 11 ...	„ p. 239.
Hatfield	June 28 ...	„ p. 240.
Plumstead and Crossness ...	July 5 ...	„ p. 265.
Malvern (Dr. Grindrod's Museum), Ledbury, Eastnor, Pendock, Tewkesbury, Woolhope.	July 21-26...	„ p. 269.

1874.

Places.	*Dates.*	*Authorities.*
Oxford, and Museum ...	April 6 & 7	Proc. iv., p. 91.
Lewisham	April 24 ...	„ p. 114.
Grays, Essex	May 16 ...	„ p. 123.
Northamptonshire, and Mr. S. Sharp's Museum	May 25 & 26	„ p. 123.
Tilburstow and Nutfield ...	June 13 ...	„ p. 153.
Hampstead, and Mr. C. Evans' Collection	June 22 ...	„ p. 155.
St. Mary's Cray, Wellhill, and Shoreham, Kent	June 26 ...	„ p. 167.

1874.

Places.	*Dates.*	*Authorities.*
Cheltenham, Cotteswold, Mayhill, Garden Cliff, Tewkesbury, Apperley, Wainlode Cliff, and Miss Strickland's and the Rev. F. Smithe's Collections ...	July 20-26 ...	Proc. iv., p. 167.

1875.

Riddlesdown and Croydon...	April 17 ...	Proc. iv., p. 283.
Watford	May 1 ...	" p. 284.
Charnwood Forest and Leicestershire; and the Leicester Museum	May 17-19 ...	" p. 307.
Watford	May 29 ...	Mr. Hopkinson in letter.
Isle of Sheppey	June 7 ...	Proc. iv., p. 320.
Erith and Crayford ...	June 26 ...	" p. 323.
South Kensington (excavations for the new Museum) ...	July 10 ...	" p. 325.
East Yorkshire; and the York, Whitby, and Scarborough Museums	July 19-24 ...	" p. 326.

1876.

Grantham and Nottingham, and Museum	April 17 & 18	Proc. iv., p. 491.
Bromley, Sundridge, and Chiselhurst ...	April 22 ...	" p. 498.
Gorge of the Medway and Kit-coty-house	May 1 ...	" p. 503.
Hatfield	May 13 ...	" p. 518.
Reading, and Mr. Palmer's Collection ...	June 3 ...	" p. 519.
Swindon (Mr. C. Moore's Swindon Collection) and Faringdon	June 5, 6 ...	" p. 543.
Sandgate and Folkestone...	June 19 ...	" p. 554.

1876.

Blackheath and Charlton...	July 1 ...	Proc. iv., p. 557.
North Wales Border, and Mr. Ruddy's Wenlock Collection ...	July 17-22 ...	" p. 559.

1877.

Places.	*Dates.*	*Authorities.*
Harwich, Felixstowe, Chillesford, and Ipswich, and Museum ...	April 2, 3 ...	Proc. v., p. 108.
Grays, Essex	April 21 ...	,, p. 125.
Wantage, and Mr. Davey's Collections ...	May 7 ...	,, p. 137.
Leicestershire, and the Leicester Museum	May 21, 22...	,, p. 142.
Caterham, Godstone, Tilburstow, and Nutfield; and Mr. Cluse's Collection	June 4 ...	,, p. 155.
Hampstead, and Mr. C. Evans' Collection	June 16 ...	,, p. 160.
Guildford and Seale, and the Rev. T. T. Griffith's Collection ...	June 25 ...	,, p. 161.
Derbyshire, and Castleton Museum ...	July 22-27 ...	,, p. 186.

1878.

Chipping-Norton ...	April 22, 23	Proc. v., p. 378.
North Downs, Surrey ...	May 6 ...	,, p. 495.
Tyler's Hill, Chesham ...	May 18 ...	,, p. 498.
Norwich and Cromer ...	June 10, 11...	,, p. 513.
Hertford and Ware ...	June 22 ...	,, p. 519.
The Gorge of the Mole, Box Hill, and Dorking	July 13 ...	Proc. vi., p. 38.
The Boulonnais; and the Boulogne and Calais Museums ...	Aug. 5-10 ...	,, p. 39.

1879.

Weymouth and Portland ...	April 14, 15	Proc. vi., p. 172.
Crayford and Erith ...	April 26 ...	,, p. 174.
Newbury, and Museum ...	May 5. ...	,, p. 185.
Orpington and Knockholt	May 10 ...	,, p. 189.
Watford	May 17 ...	,, p. 191.
Knockholt and Sevenoaks	May 24 ...	,, p. 194.
Bath (and Museum) and the Vallis ...	June 2, 3 ...	,, p. 197.
Sevenoaks and Tunbridge...	June 14 ...	,, p. 202.
Tunbridge and Tunbridge Wells ...	June 28 ...	,, p. 204.
Tunbridge Wells and Crowborough ...	July 12 ...	,, p. 230.

1879.

Places.	*Dates.*	*Authorities.*
Ledbury, May Hill, Knightwick, Malverns, and Woolhope; and Mr. Piper's Collection	July 21-26 ...	" p. 233.

1880.

The Hampshire Coast ...	March 29, 30	Proc. vi., p. 316.
Camberley (Prof. Rupert Jones's Collection) and Easthampstead Plain	April 24 ...	" p. 329.
Upnor	May 8 ...	" p. 336.
Oxford, and Museum ...	May 17 & 18	" p. 338.
Aylesbury	May 29 ...	" p. 344.
Croydon and Riddlesdown	June 19 ...	" p. 372.
Redhill and Nutfield ...	June 26 ...	" p. 373.
Maidstone, (and Museum)	July 11 ...	" p. 392.
Leith Hill and Dorking ...	July 24 ...	" p. 393.
Bristol and Museum, Clevedon, Aust Cliff, Weston, Cheddar, Wells and Radstock	Aug. 16-21...	" p. 396.

VISITS TO MUSEUMS IN LONDON, &C.

1862.

Museums.	*Dates.*	*Authorities.*
British Museum ..	March 4 ...	Proc. i., p. 247.
International Exhibition ...	Oct. 23 ...	" p. 269.

1863.

South Kensington Museum	? ...	Proc. i., p. 358.
Museum of Practical Geology	July 18 ...	" p. 351, 358.
Kew Gardens and Museum	? ...	" p. 358.
Zoological Gardens ...	? ...	" p. 358.
British Museum ...	? ...	" p. 358.
Hunterian Museum at the Royal College of Surgeons	? ...	" p. 358.

1864-6.

See p. 29, and the foregoing list, p. 49.

1867.

International Exhibition at Paris ...	July ...	Annual Report for 1867.

1868.

See the foregoing list, p. 49. Nothing mentioned in the "Annual Report for 1868."

1869.

See the foregoing list, p. 50. No other visits to Museums &c., reported or referred to.

1870.

Museums.	*Dates.*	*Authorities.*
British Mus., Geological Department ...	March 23 ...	Proc. ii., p. 4.
Museum of Practical Geology	April 2 ...	„ p. 28.
British Museum, Palæontological Dept. ...	April 12 ...	„ p. 28.

1871.

British Museum ...	March 18 ...	Proc. ii., p. 183.
Museum of Practical Geology	March 25 ...	„ p. 184
Hunterian Museum, Royal College of Surgeons	April 18 ...	„ p. 227.

Nine private Collections are enumerated (see also the other list) in the "Annual Report for 1871," p. 4, as having been visited.

1872.

Museum of Practical Geology	March 21 ...	Proc. iii., p. 38.
British Museum ...	May 11 ...	„ p. 86.
International Exhibition ...	July 13 ...	„ p. 123.

1873.

British Museum	March 27 ...	Proc. iii., p. 189.
Hunterian Museum ...	April 3 ...	„ p. 190.
Museum of Practical Geology	April 21 ...	„ p. 205.
The Brighton Aquarium ...	June 11 ...	Annual Report for 1873, p. 5.

Eleven local Museums and the Collections were visited this year (p. 51).

1874.

British Mus., Mineral Dept.	March 24 ...	Proc. iv., p. 91.
British Mus., Palæont. Dept.	April 18 ...	„ p. 113.

And five local Collections (see the other list). "Annual Report for 1874;" "Proceed." iv., 207.

1875.

Museum of Practical Geology	April 3 ...	Proc. iv., p. 281.

For local Collections, see the other list, p 52.

1876.

British Museum ...	March 18 ...	Proc. iv., p. 480
Museum of the Geological Society ...	April 1 ...	„ p. 483.

For local Collections, see the other list, and "Annual Report for 1876," p. 6.

1877.

Museums.	*Dates.*	*Authorities.*
British Museum; Fossil Marsupials ...	March 17 ...	Proc. v., p. 103.
British Museum; Fossil Fishes ...	March 24 ...	„ p. 106.
British Museum; Fossil Reptiles ...	April 14 ...	„ p. 122.
Hunterian Museum ...	May 12 ...	„ p. 140.

1878.

British Museum; Ceratodus	March 16 ...	Proc. v., p. 363.
British Mus.; Botan. Dept.	March 23 ...	„ p. 365.
Crystal Palace, Sydenham	April 6 ...	„ p. 377.
Zoological Gardens ...	June 5 ...	„ p. 511.

1879.

British Museum; Dinosauria	March 15 ...	Proc. vi., p. 151.
British Mus.; Cephalopoda	March 29 ...	„ p. 151.
Hunterian Museum ...	April 5 ...	„ p. 171.

1880.

Museum of Practical Geology	March 13 ...	Proc. vi., p. 311.
British Museum	April 10 ...	„ p. 321.
Kew Gardens and Richmond	June 19 ...	„ p. 372.

APPENDIX III.

THE GEOLOGISTS' ASSOCIATION REPRESENTED AT THE COMMEMORATION OF THE GEOLOGICAL SOCIETY OF FRANCE, ON APRIL 1ST, 1880, BY THOMAS DAVIDSON, ESQ., F.R.S., F.G.S., Hon. Mem. Geol. Assoc., &c.

In answer to a notification from Mr. T. DAVIDSON, F.R.S., that he was about to attend the Half-century Commemoration of the Geological Society of France as Delegate from some of the Scientific Societies of London, Edinburgh, Glasgow, and Dublin, and would be pleased to represent also the Geologists' Association on that occasion, the following letter was written to him —

"MY DEAR DAVIDSON,—

"I hasten to reply to your letter of yesterday, by saying that the Geologists' Association in general, and its President in particular, will be greatly obliged by your representing us at the approaching Commemoration of the Geological Society of France, and by expressing our cordial

sympathy with that excellent Society in the pleasure and satisfaction arising from a knowledge of the scientific good it has accomplished in its Fifty Years of existence, and of the goodwill and friendly feeling it has cultivated among Geologists of many lands for so many years. The gratitude we owe to many of its earliest Members is the same as that which we owe to English Geologists of repute who have passed away, but have left good words and works behind for us.

"We ourselves (the Geologists' Association) held lately a Memorial Dinner in honour of our arriving at the age of Twenty-one Years; and if we had to congratulate ourselves on a youth well spent, your esteemed Society must indeed be proud of the fruits of their manhood, and of the many rising Geologists affiliated to the Society. You may well look forward to very many successive generations of good and true Geologists pursuing their useful work and bringing honour to the Geological Society of France.

"The Geological Association was founded in January, 1859 [December 1858] by many young men wishing to learn Geology economically and by the mutual help of talking over specimens and at geological localities, with real sections before them, and with other aids to mutual improvement arising from intercommunication both in London and the country. They began with about 250 Members, and we have now more than 400.

"We had more than 100 at the Memorial Dinner on the 4th instant, and some excellent speeches were given by Hyde Clarke, Wiltshire, A Tylor, Prof. Owen, John Jones, Lobley, James Parker, Prof. Morris, Carruthers, Etheridge, Prof. Bonney, H. Woodward, E. B. Tylor, C. C. King, and others.

"You will kindly oblige me by personally remembering me, with kind regards and good wishes, to Daubrée, Delesse, MM. Milne-Edwards, *père et fils*, Gaudry, Hébert, Meunier Chalmas, E. Sauvage, Gosselet and Barrois of Lille, Louis Lartet of Toulouse, Barrande, Dollfus, and others who may hold me in kind remembrance, whether of France, Germany, Italy, or elsewhere, should you encounter them.

"Believe me, Dear Davidson,

"Yours very truly and obliged,

(Signed) "T. Rupert Jones,

"Pres. Geol. Assoc."

"Camberley, Surrey,

"March 11, 1880."

Mr. Davidson, after his return from Paris, describes, in a letter to the President, the very distinguished reception he met with as the Delegate of ten of the chief Scientific Societies in Great Britain and Ireland, and the evident esteem and friendship felt by the savants of France for their British collaborateurs. An official account of Mr. Davidson's mission as Delegate to the Commemoration is given in the "Quart. Journ. Geol. Soc.," No. 143, for August, 1880.

ORDINARY MEETING.

NOVEMBER 5TH, 1880.

PROFESSOR T. RUPERT JONES, F.R.S., F.G.S., President, in the Chair.

The Donations to the Library, received since the previous meeting, were announced, and the donors received the thanks of the Association.

The following were elected Members of the Association :—

C. R. Haeusler, Esq., F.G.S., Samuel Henson, Esq., Alf. Lovell, Esq., Oliver Giles, Esq., F. Chas. Margetson, Esq., Evan D. Jones, Esq., Thos. S. Conisbee, Esq., F.G.S., and H. S. Cotton, Esq.

The President then delivered the Inaugural Address of the Session, 1880-1881, as printed above.

Duplicates of rocks and fossils were brought by one of the Members for distribution.

ORDINARY MEETING.

DECEMBER 3RD, 1880.

PROFESSOR T. RUPERT JONES, F.R.S., F.G.S., President, in the Chair.

The Donations to the Library, since the previous meeting, were announced as usual, and the donors received the thanks of the Association.

The following were elected Members of the Association :—

Geo. Lingwood, Esq., Mrs. M. M. Daniell, Rev. Fredk. Hastings, Rev. H. P. Stokes, Jas. Fox, Esq., C. R. Nunn, Esq., Mrs. Winser, H. R. Ladell, Esq. M.A., F.G.S., and Rev. J. T. Bell.

The following paper was read :—" On some Recent Researches among pre-Cambrian Rocks in the British Isles," by Dr. Hicks, F.G.S.

The following specimens were exhibited on the table :—

1. A large series of rocks from the pre-Cambrian formation of St. David's Head. Exhibited by Dr. Hicks.

2. Cut and polished agates. Exhibited by Mr. Needham.

On some Recent Researches among pre-Cambrian Rocks in the British Isles.

By Henry Hicks, M.D., F.G.S., V.P., Geol. Association, &c.

It occurred to me that as pre-Cambrian Geology has received of late years a considerable amount of attention in this country, it may interest the Members of this Association to have placed before them some of the results obtained from the more recent researches amongst the rocks of that age. I will not attempt to review the history of the earlier researches, which were mainly confined to Scotland, as you have already had the advantage of the elaborate paper by Mr. Hudleston, where these have been very fully referred to.

Up to the year 1863, when I commenced to work amongst the older rocks of St. Davids, the only rocks in England or Wales which had been even doubtfully assigned to a pre-Cambrian age, were some crystalline schists in Anglesea, referred by Prof. Sedgwick to " a distinct epoch from the other rocks of the district, and evidently older ; " hence, doubtless, meaning that they were older than the Cambrian rocks in the neighbouring mainland in Caernarvonshire.

In his descriptions and sections he referred the schists only, as was done also in Scotland, to this age, believing that the great granitic and felsitic patches, which we now refer also to that age, were composed of intrusive rocks of a much later date.

In the year 1864 Dr. Holl * referred the crystalline schists, forming the Malvern Hills, to a pre-Cambrian age ; and in the same year Mr. Salter and myself described some rocks at St. Davids, which we also assigned to that age. At this time the only rocks mentioned as characteristic of the pre-Cambrian age, in any of the areas where they were known, were such as would be included

* " Quart. Journal Geolog. Soc.," vol. xxi., p. 72.

under the name crystalline schists; therefore, when I commenced my researches at St. Davids, my difficulties were considerable, fo though the evidence seemed tolerably clear that rocks of pre Cambrian age occurred there, yet these appeared to presen characters so entirely unlike any that had been previousl described as belonging to that age, that for some time I felt necessary to speak with considerable hesitation, fearing lest th further evidence, which it was thought necessary to obtain, woul not bear out the conclusions.

For instance, it seemed difficult to realise that the so-calle intrusive masses of granite and syenite could be metamorph rocks, and, yet, though they appeared as if penetrating throug the Cambrian rocks, there was no evidence anywhere of contac alteration, or irregular intrusion into, or of their having produce any disturbance in the overlying rocks. The only solutio possible seemed at first to be that they were igneous rocks pre-Cambrian age. Further evidence, however, seemed to sho that the latter view could not be the correct one in regard to th majority, and that after all we had here the metamorphic rock but unlike in several particulars and in a very massive state, compared with those previously found in other areas. Thes peculiarities became subsequently known as characteristic, to great extent, of the Dimetian series, and enabled the grou afterwards to be recognisable by these characters in North Wal and elsewhere.

In addition to the granitic and syenitic ridges, there were man others described as composed of intrusive masses of felstones ar poryphyries. That these rocks must, in the main, have had igneous origin, seemed tolerably clear, but, on careful examinatio they again did not appear to behave in the usual manner intrusions amongst newer sediments. Some also, classified und these names, it soon became evident were mainly breccias indurated ashes. The result of continued examination was to sho that the majority of the rocks, placed under these heads, in tl neighbourhood of St. Davids, were also of pre-Cambrian age, ar these are now usually defined by us under the name—"Arvoni Group."

In addition to these there were large areas of rocks described altered Cambrian. The alteration being supposed to be chief due to proximity to the so-called igneous masses above referr

to. Now, as these masses could not possibly, according to the view we held, have had any influence whatsoever on newer sediments, it became evident at once that some other reason than that adduced would have to be sought for to account for the presence of such an altered series. On examination it was found that these rocks were entirely unlike those in the overlying Cambrian group, and, moreover, that whenever the junction between the two could be found, they never passed into one another, but that they were separated by a great thickness of conglomerates composed almost entirely of masses of rocks identical with those below, belonging to the metamorphic series. Hence it was that our third, or Pebidian group, came to be differentiated. Such, in brief, may be said to be the history of the discovery of the three groups at St. Davids; and as most of the data upon which we have depended in our subsequent investigations in other areas, were derived from these researches at St. David's, I purpose now to refer more minutely to the special or predominating characters exhibited there by each group.

Dimetian.

The rocks included under this name are coloured on the Survey Maps as Granite or Syenite, intrusive amongst Cambrian rocks. On examination it is found that they everywhere show more or less distinct lines of bedding, striking from about N.W. to S.E. They vary also, to some extent, in their mineralogical characters, if examined at different points, and have apparently an order of succession in which these changes occur at recognisable horizons. The prevailing rocks in this group are of a granitoid character, usually of rather a massive, but sometimes of a schistose nature.

Sometimes almost pure quartzites are found, but by far the largest proportion contain an admixture of felspar of a white or pinkish colour. Specks of viridite usually occur more or less throughout, and sometimes give quite a tinge to the rock. Mica occurs sparingly, for the most part, but there are occasionally micaceous, chloritic, impure limestone and serpentinous bands. At some places also thin, compact, white bands of a more highly felspathic character occur. Some of the beds assume a brecciated

appearance, the masses being generally angular or sub-angular, and in composition much like the associated rocks.

Speaking generally, the majority of the rocks comprising this group are highly quartzose, of a granitoid or rather massively gneissic nature, and usually easily recognisable by these characters; their strike is from about N.W. to S.E.

Arvonian.

The rocks now included in this group I originally associated with the Dimetian, but in the year 1878 I separated them from the latter, under the above name.

On the Survey Maps they are coloured generally as felstones and porphyries, usually intrusive amongst Cambrian or Lower Silurian rocks. They consist in reality of flows of rhyolitic lavas, alternating with felsitic breccias and hälleflintas. The strike is from N. to S., and, hence, discordant to those newer rocks with which they are usually surrounded, as also to the underlying Dimetians. Like the Dimetian, this is a highly acid group, being mainly made up of the types of rocks known as the quartzo-felspathic. But, instead of being like these, chiefly of clastic origin, we have here a great series of acid lavas mixed up with a comparatively small proportion only of rocks of a clastic nature. In colour these lavas vary from being very dark (almost black) to a light grey, and from deep red or violet to flesh-colour. The flow-structure is usually well marked, and in many cases the spherulitic structure also. A large number are porphyritic, from minute crystals of felspar or quartz. The hälleflintas are more siliceous looking than the rhyolites, and have a horny-looking texture and fracture. Under the microscope they are still more easily distinguishable. Their chief peculiarity, perhaps, consists in the manner in which some of the quartz becomes separated away into nests, so as to give the rock a curious pseudo-porphyritic appearance; whilst the intervening parts exhibit the appearance of a micro-crystalline mass of quartz grains, with intervening felsite. The breccias usually consist of fragments of lavas and hälleflintas, like those in association with them, and the pieces angular.

This group, therefore, is characterised by being for the most part made up of acid lavas, breccias, and compact siliceous rocks of the hälleflinta type, and as having usually their strike in a direction from N. to S.

Pebidian.

Most of the rocks in this group differ from those already described, though occasionally there is a certain amount of resemblance remaining. Instead of the acid types prevailing as in the previously named groups, we find the basic types more largely developed. Basic lavas and breccias now predominate over the rhyolites, and the clastic rocks are more micaceous, chloritic and talcose. On the Survey Maps these rocks are coloured as altered Cambrian, and partially as intrusive greenstones. On more careful examination the so-called greenstones turn out to be bands of indurated volcanic ashes, and contemporaneous basic lava-flows. Agglomerates and breccias occur in great thicknesses in the group, and the fragments are chiefly, except in the lowest beds, of a basic character. Chloritic, talcose, felspathic and micaceous schistose rocks occur also at various horizons, and occasionally purple and green slates. Serpentinous bands are also sometimes found, as well as veins of jasper, epidote and asbestos. Some of the finer and more quartzose beds assume a gneissose appearance, and others are porcellanitic.

The strike in this group is from about N.E. to S.W., and hence nearly in accordance with that in the overlying Cambrian rocks. That this group, however, must have been in much the same condition in which it is now found, before a grain of the Cambrian rocks was deposited, is perfectly clear from the fact that the conglomerates at the base of the latter are very largely made up of rolled pebbles and rounded fragments identical with the rocks below. An actual unconformity between the two groups is also seen at several points.

This group consists of a far more varied series than the two former, and doubtless would exhibit a still greater diversity if fully exposed, for it is perfectly clear that, in consequence of the rapid overlapping of the sections by the Cambrian rocks, much is hidden from view.

Having thus sketched out the chief results obtained by the examination of these ancient rocks at St. Davids, I purpose referring to some of the other areas, where the facts are almost equally clear, before referring to those where the evidence may seem to some less conclusive, though, in my opinion, sufficiently satisfactory.

Harlech Mountains.

Here, as at St. Davids, the Cambrian rocks occur in development, and, until very recently, were supposed to unusual thickness. The estimates given had varied consid it was supposed that the basal beds were nowhere exposed. visited the neighbourhood on several occasions and reco great similarity in the Cambrian series to that I had ma St. Davids, I felt, some years ago, convinced that search along the centre of the broken anticlinal would show that the basal beds were there exposed, but moreo some remnants of the old pre-Cambrian land would also l Last year, after examining a section I had not previousl accompanied by Mr. Spratling, I satisfied myself convictions were fully warranted by the conditions e and, this year, further explorations along different this area with Prof. Hughes added numerous import confirmatory of these views. Some of these I now referring to. The Lower Cambrian rocks at St. Davic generally estimated at about 5,000 feet, whilst the lowest that has been given of the Harlech rocks has been over 8 and from that up to 20,000ft. Now a difference even of 3 is considerable in areas so near each other, especially consider that the sediments in each case give indications o been deposited under very similar general conditions. A over, most of the beds are ripple-marked in each area this i thickness could only take place if a far more rapid depres place here than at St. David's, with accumulations corresp more rapid also. Looking at the whole series up to the fos Menevian beds, which, in passing, I may say are curio those at St. Davids, I see nothing to show that the conditions—even after allowing for the inequalities of the of the old pre-Cambrian land, which it is probable would b effaced after depression, and an accumulation of 1,000 fe otherwise than alike in both areas, which together form small part of a large area of depression extending not o the British Isles, but also over the greater part of Europe

The higher ridges and plateaux would of course rema water in the areas where they occurred, and the sedimen vary in proportion to proximity to these, but for general we find that over the Welsh areas these did not greatly

with the order of succession. Subordinate beds of conglomerates certainly do occur at St. Davids, as well as in the Harlech Mountains, at different horizons, showing, probably, a proximity to small unsubmerged portions; but these cannot be confounded with the thick massive beds with large pebbles, which, in both areas, occur at the base of the whole Cambrian series. In these beds the fragments of the older rocks are sometimes almost angular, many of great size, and all indicating that they must have been shore accumulations, and carried but a short distance.

In this way we reason, and, I think, fairly, that at this period new physical conditions on a very large scale were taking place over the British Isles, such, indeed, as have probably never since been equalled, and that a fresh order of things must then have set in. It is from this time forward also that nearly all the evidence hitherto relied upon in enquiries as to the real physical history of the globe, and of what is generally indicated as geological chronology, has been derived. That period which preceded it was until lately looked upon as a blank, but I feel bold enough now to say that this cannot possibly be the case in future, and that pre-Cambrian time will be found to have a history not less interesting than that which has succeeded it, and as important to unravel in every geological sense. The problems to be solved are, many of them, difficult, but this should only make us the more anxious to attempt by persistent labours, and by the assistance of the numerous new aids which science is capable of commanding, to do our best to solve them.

No better evidence of the character of the rocks which composed the old pre-Cambrian land can be had than that derived from a careful examination of the various masses contained in the Cambrian conglomerates, for undoubtedly these, at least, must have been derived from pre-existing rocks. For some time past I have been collecting evidence, from an examination of these masses from various areas, to arrive at some idea of the prevailing rocks which must have been exposed when these were deposited, as this cannot fail to aid us in our search for the fragments of the old land which may now remain exposed. At St. Davids bits belonging to nearly all the rocks now recognised as pre-Cambrian may be found either in the conglomerates which separate the groups or in those at the base of the Cambrian. In addition to these, however, there are frequently masses which must

either have been derived from a distance or from some rocks whi are not exposed in the neighbourhood at present. That they m have been derived from a distance is quite possible, as previous the depression of the old land the surface was doubtless partia covered by much loose material conveyed from one part to anoth by the aid of ice, rivers and other agencies. As at St. Davids, in the Harlech Mountains, we find that the conglomerates conta not only abundance of fragments similar to the rocks below, b also numerous others whose original locality must be sought elsewhere. The pre-Cambrian series as exposed here approach nearer to that of the Pebidian than to either of the other grou and it is with that group I propose to associate the chief portion present. The strike is generally from about N.E. to S.W., but varies sufficiently from that in the Cambrian rocks to enable us recognise how the overlapping takes place, especially as the dip usually much higher in the pre-Cambrian than in the Cambrian.

Of the fragments abundant in the conglomerates I may me tion quartz felsites and felspathic schists, and purple and gre slates and shales, all of which are found in *situ* in the i mediate neighbourhood. Of others not found at hand are gran and gneiss rocks, mica-schists, talcose and chloritic rocks, quartzit vein quartz, jasper, &c.

Caernarvonshire.

The next areas which I shall refer to are in Caernarvonshire and here, again, it will be seen that the Cambrian and pre-Cambrian rocks occur in association. One of these areas I described in a paper to the Geological Society in 1877. It extends from the neighbourhood of Moel Tryfaen by Llyn Padarn in a N.E. direction to Bethesda. In it are found quartz-felsites, rhyolites, felspathic breccias, and schistose rocks, similar to those described in the Arvonian group at St. Davids; but along the flank of these other rocks occur, which are more like members of the Pebidian group, and in a paper in 1879 I endeavoured to separate the two groups. In tracing the Cambrian conglomerates, which occur almost continuously along the sides of these rocks, we notice particularly that upon whatever series they rest, a proportionate increase of pebbles identical with the rocks of that series are found. For instance, at Moel Tryfaen, where schistose rocks mainly occur, the pebbles in the conglomerates are chiefly of a

schistose nature; whilst at Llyn Padarn, where quartz-felsites and rhyolites occur, the pebbles are very largely made up of rocks of that character. This indicates, to my mind, that we have here undoubtedly an old coast line, and that these were the true beach accumulations on that old shore.

Another important area in Caernarvonshire was partially referred to by me in my paper in 1877, and also by Prof. Hughes in his paper at the same meeting. It extends in a N.E. direction from Caernarvon to Bangor. At the former place granitoid rocks of the Dimetian type, with a N.W. strike, are found; between these and Bangor quartz-felsites, rhyolites, breccias and hälleflintas, like those in the Arvonian group at St. Davids, occur, and with a N. and S. strike. Nearer to, and about, Bangor, agglomerates, breccias, porcellanitic rocks, chloritic schists, &c., are found, which have a N.E. and S.W. strike, and which are identical in character with many of the rocks found in the Pebidian group. Cambrian conglomerates are found resting on the different groups at various points, and, like those in the other areas referred to, contain masses of these in proportion to their proximity or otherwise to the several series.

Here, therefore—in two areas, at least, in Caernarvonshire—we have, it appears to me, very strong proof of the presence of portions of the old pre-Cambrian land, and of the accumulations which took place around its shores.

I may now, perhaps, presume that the evidence which I have brought forward, and which I might have greatly strengthened by referring to the very careful microscopical labours which have been bestowed upon these rocks by Mr. T. Davies, and by Prof. T. G. Bonney, will be considered sufficiently convincing by most persons in regard to the areas already referred to.

I fear, however, it will not be considered equally clear in regard to some of those which I purpose now referring to, for although the evidence to my own mind might be equally satisfactory, yet it frequently happens that it cannot be readily demonstrated. Moreover, cases arise where the facts are ample to render their pre-Cambrian Age probable, though the evidence may not be considered conclusive.

In my paper in 1870 I mentioned several areas in the Lleyn promontory, where I considered pre-Cambrian rocks were to be seen. In the mountains called the Rivals, I recognised rocks so

identical in character with those at Llyn Padarn, Moel Tryfaen, and near Bangor, that I ventured to associate them with the Arvonian rocks of the pre-Cambrian. I did this, moreover, on other grounds besides identity in mineral characters. In examining the surrounding rocks, I found that all were of the type of sediments known as dark ferruginous slates and flags, so characteristic of the late Cambrian or very early Silurian period, as generally exhibited in North and South Wales; whilst in the Rivals themselves nothing but rocks of a higher siliceous type occurred. Moreover, it was soon seen that the latter consisted largely of rhyolitic lava-flows and breccias, and that they could not have been intruded into, or have been inter-stratified with, the surrounding argillaceous slates and flags. One important fact which contributed to my arriving at this conclusion was that even on the Survey Maps they had found it impossible to show these and other masses in the area to be inter-stratified with the slates, as they had done with some in the Arenig and Bala districts, but had been compelled to indicate them as intrusive masses breaking through the slates. Another important fact arrived at during this examination was that some of the surrounding slates were found to contain fossils belonging to the Tremadoc group, and hence to be considerably older than previously supposed. As no contemporaneous lavas of that age were known anywhere else in North Wales, this evidence seemed of some importance. Moreover, the intrusive theory could not possibly account for the conditions observed. There was no contact-alteration to be seen, no irregular penetration, and the rocks themselves, for the most part, were not of the types considered usually as intrusive. They have been, in some cases, traversed by dykes of a later date, and by some others which I believe to belong to pre-Cambrian times, but which cannot be easily differentiated from intrusive rocks of a later period.

The only theory which seemed to me, therefore, possible was that these rocks, so identical in their mineralogical and physical characters with those found elsewhere, as typical of some pre-Cambrian groups, must also belong to that age, and that the newer rocks which were now in contact with them had been brought into that position by faults. In many cases, also, there was clear evidence to show that the junctions were lines of

fault. Some, however, may raise objections to this theory, and argue that the faults necessary would be enormous. To this I reply that faults of equal and greater magnitude are quite common in the other pre-Cambrian areas, and that it is not at all unusual to have one edge of the pre-Cambrian fragment covered with Lower Cambrian rocks, whilst the other edge is in contact with those of Lower Silurian age.

If we remember that the pre-Cambrian rocks before they were depressed to receive any of the Cambrian sediments were not only in an indurated state, but also highly metamorphosed, we may readily see how it must have taken place, that during the various changes to which the crust has been subjected since that time, fracture after fracture much have occurred—sometimes parallel to, sometimes across the bedding, and sometimes even redisturbing connections previously produced, perhaps, by the same cause.

A clear recognition of the probable effects produced by the repeated contractions of the crust, on these older metamorphic rocks, covered, as they were, by great thicknesses of superincumbent sediments, is, perhaps, of all things, the most necessary when we commence to explore amongst them.

Sometimes a small fragment only of the old land is seen, bounded by faults and surrounded by comparatively recent sediments. In another place a large piece occurs, and the newer rocks have been dropped into the midst of it at different points, also as the result of faults. Such occurrences as these must always render the explorations difficult, but certainly not less interesting to the really enquiring geologist.

Towards the point of the Lleyn promontory a considerable area is coloured on the Survey Maps as altered Cambrian, bounded on the east by Syenite. Our examinations soon demonstrated that the so-called Syenite was in no way the cause of the alteration in the associated rocks, but that it really was itself of metamorphic origin and of Dimetian age, and that the so-called altered Cambrian rocks consisted of a series of breccias, volcanic ashes, and schists mainly of the type of the Pebidian rocks at St. Davids.

The condition of things in this promontory was found to be so similar to that in the promontory of St. Davids that it could not fail at once to suggest the correlation of two of the groups. On further examination, rocks of the Arvonian type were also found ;

so we have here again the three pre-Cambrian groups represented in a comparatively small area.

Anglesea.

As already mentioned, some of the schists in Anglesea were, many years ago, described by Prof. Sedgwick as forming the base of the Cambrian series, not perhaps as a pre-Cambrian group, but at all events as the oldest rocks in the district.

The Geological Surveyors, however, did not agree with this view, and arrived at the conclusion that these schists were merely the altered representatives of the Cambrian, and probably in part of the Silurian, rocks found on the mainland in Caernarvonshire. My recent explorations amongst these rocks compel me to agree rather with the views of Prof. Sedgwick than with those of the Survey; but I have ventured to go farther, and have included amongst the pre-Cambrian rocks others which had been previously supposed by all geologists who had explored them to be intrusive rocks of a much later date. I have also obtained much evidence which has enabled me to attempt to correlate the several series found in Anglesea with those in the other areas described. Near the centre of the Island, running in a north-east direction, a large patch is coloured as granite in the Survey Maps. This I found, in 1878, to be composed mainly of a series of gneissic rocks, similar, for the most part, to those composing the Dimetian group in Caernarvonshire and at St. Davids. It could not possibly, therefore, be an intrusive granite of later date than the surrounding series, as supposed by the Survey, nor could it have in any way tended to produce the metamorphic change in that series supposed to have been induced by it. On the one side, also, Silurian rocks were found in an entirely unaltered state, and more recently Prof. Hughes has been able to prove conclusively that some of these unaltered sediments must be Lower Tremadoc rocks, and hence of Upper Cambrian age. My interpretation at present of the older rocks in Anglesea is that the granitoid gneiss, already mentioned, is a part of an important axis, in which the oldest rocks in the island are found—that along one side this is flanked by rocks of the Arvonian type, and that these are succeeded by the schists and breccias, which have a N.E. and S.W. strike, and which are, for the most part, of Pebidian age.

That there are at least two other axes of older date than the rocks with the N.E. strike is more than probable; one of these occurs in the neighbourhood of Holyhead and another near the Menai Straits. Here and there Cambrian and Silurian rocks seem to have been dropped amongst the older rocks by faults, as in the Lleyn promontory, but these are generally easily recognisable, even when not fossiliferous, by their unaltered condition, and by being chiefly of the type of the argillaceous sediments characteristic of the Cambrian and Silurian rocks on the mainland. That the metamorphic rocks in Anglesea are all of the types of rocks recognised elsewhere as typical of the pre-Cambrian rocks, there cannot be a doubt. Moreover, I venture to state that there is hardly a rock amongst them of which I have not seen specimens in the Cambrian conglomerates. The rocks of Dimetian type have the normal strike of that group. Those also which resemble the Arvonian have their strike, and the very varying series characteristic of the great Pebidian groups have the strike everywhere more or less evident in it. That some of the rocks found here have not been discovered in the other areas is not at all to be wondered at, for in no place can it be said that we have seen them in their full development—especially as they are usually quickly overlapped by the Cambrian rocks. That the highest series, however, has the normal strike of the Pebidian group, and that fragments of every type in that series are frequently found in the Cambrian conglomerates, are, to my mind, very strong proofs that it belongs to that period in the history of the globe, when the Pebidian rocks were deposited.

Shropshire.

In the year 1877, the important announcement was made by Mr. S. Allport that the Wrekin ridge and another area to the N.W., coloured as greenstone in the Survey Maps consisted almost entirely of a "series of ancient vitreous and semi-vitreous lavas, with their associated agglomerates and ashes," and that the term greenstone was the most inappropriate that could possibly be applied to them. He also says that they "all belong to a highly acid type, and have not the slightest resemblance whatever to greenstone or any other rocks of

the basic series." In regard to the age of the series he supposed them to belong to the "older contemporaneous volcanic series, so extensively developed in the Lower Silurian district of Salop and Radnor." In the same year, Dr. Callaway announced that a "part of the so-called quartzite between the shale (Shineton) and the Wrekin represents the Hollybush Sandstone of Malvern," and that he had "satisfied himself that the so-called greenstone of the Wrekin and neighbouring areas is largely composed of bedded rocks." Since that time, Dr. Callaway has paid much attention to these rocks, assisted by Prof. Bonney, and the result has been that they are now classed with the pre-Cambrian rocks. Hitherto they have described two groups only from that area—viz., the Dimetian and Pebidian—but after carefully examining many of the specimens collected, and also the rocks in the field, I feel tolerably convinced that there are representatives of the three groups, and that some of those now classed by them with the Pebidian must, on physical and mineralogical evidence, be assigned to the Arvonian.

The Malvern Hills.

Since Dr. Holl published the results of his labours in 1864, very little additional information concerning the rocks composing these hills has been forthcoming. Last year, however, Dr. Callaway announced, at the field meeting of this Association, that he had recognised, in a spur from the Herefordshire Beacon towards the S.E., a series of rocks very unlike those composing the main portion of the ridge, and that they were in appearance much like some of the Pebidian rocks which he had seen at St. Davids. In company with many members of the Association, guided by Dr. Callaway, I had the pleasure of examining these rocks in the field, and, I may say, formed at once the same conclusion that Dr. Callaway had—that they must belong to that group. Since then he has published the results of further examinations, which are in every way confirmatory of his previous conclusions. As to the rocks which compose the main portion of the ridge, I can at present only say that, on the whole, they more resemble the Lewisian rocks of the N.W. of Scotland and the Hebrides than any other rocks I am acquainted with; but that, withal, it is probable some representatives of the Dimetian rocks are also be found there.

Charnwood Forest.

The older rocks in this area have of late years been very carefully studied by Messrs. Hill and Bonney, of Cambridge, and, as they are now supposed by these authors to be "probably pre-Cambrian," I venture to refer to them. In their first paper they associated them with the Lower Silurian rocks. At that time, however, I ventured to suggest that they would ultimately turn out to be of pre-Cambrian age, from an examination of the specimens collected by those authors.

In this area the rocks are described as consisting of "slaty and gritty beds, of thick masses of coarse agglomerate of a rhyolitic type, though less glassy than those which occur in the Wrekin, and of still more extensive deposits, which seem to be composed of volcanic materials slightly rolled and arranged by water." By the Geological Survey these rocks have been called Cambrian; but, as I have already shown in other areas, it will be observed from the above descriptions that they are in no way like those rocks, but resemble in a very marked degree some of the pre-Cambrian rocks, especially those belonging to the Pebidian Group.

Cornwall.

For some years past I have believed that pre-Cambrian rocks would be found in Cornwall, and it appears now that this is likely to be proved ere long to be a fact. The researches of Mr. Collins in the Meneage Peninsula, and of Mr. A. R. Hunt along the coast of South Devon and Cornwall, have brought to light some new facts which are, in my opinion, almost conclusive of the presence in those areas of rocks of pre-Cambrian age. I must, however, state that neither of these authors have as yet committed themselves to the view that these are pre-Cambrian rocks. Still, Mr. Collins has stated that there are some of "pre-Silurian age," and Mr. Hunt has granted the possibility of the rocks he has examined being pre-Cambrian. I have seen some of the specimens collected by the latter, and believe that among them there are types only known in the pre-Cambrian rocks in this country. At present, however, it would be unsafe to theorise upon the evidence available, but no harm can arise from referring briefly to the facts. It is well known that the Eddystone Lighthouse is built upon rocks of a gneissose type—some massive, others more schistose. These gneisses appear to be of the

true type of the older or granitoid kind, hence rendering it probable that, in the Channel at least, a ridge of these older rocks occurs. Mr. Hunt, when reading his recent paper at the British Association, exhibited numerous masses which he had dredged up off the coast of South Devon and Cornwall, and amongst them a very large number were found to be gneiss rocks. Some pieces of a conglomerate were also found, and in these distinct fragments of older rocks occurred. These, as suggested by Mr. Tawney—to whom they were first submitted—appeared so exceedingly like a conglomerate near Caernarvon, in North Wales, that it would be impossible almost to distinguish bits of the one from the other. The hornblendic and serpentinous rocks of Cornwall are so well-known that I need only refer again to the fact that Mr. Collins has separated them from the Silurian rocks, and that he believes the latter are unconformable to, or faulted against, the former.

If this be the case, it seems to me only reasonable that we should associate them with the metamorphic pre-Cambrian rocks which they most resemble, rather than with the Silurian or Cambrian rocks, which, as we have already shown, are usually so entirely unlike them.

Scotland—North-West Coast.

But few researches seem to have been made amongst the pre-Cambrian, or so-called fundamental gneiss, rocks in Scotland of late years, and in regard to some areas, such as the Hebrides and the extreme North-West Coast, little is known beyond what is given in the well-known papers by Prof. Nicol and Sir R. Murchison.

Having, however, on different occasions visited some of the other areas, I purpose referring briefly to the results obtained, and the conclusions arrived at. These, I fear, will not be found to accord in some important particulars with the views of previous writers. Some of the results have been already published,* but others have been either but briefly touched upon or not referred to at all. The so-called fundamental rocks along the North-West Coast of Sutherland and Ross have been by most authors considered as belonging to one group, and designated under the names of Laurentian, Lewisian, or Hebridean. In examining some of these areas, particularly about Gaerloch in Ross, I was struck with the general want of resemblance of the rocks to

* "Quart. Journal Geolog. Soc.," 1878, and "Geolog. Mag.," 1880.

those which have been usually described as characteristic of those areas. Instead of the very massive granitic gneisses and hornblendic rocks commonly mentioned, I found the majority to be rather thin-bedded schistose rocks, the gneisses to contain usually black mica instead of the hornblende described as characteristic of them, and to be, on the whole, far more quartzose than was usually supposed to be the case. Moreover, chloritic and other distinct rocks occurred plentifully in some places. That all these also were undoubtedly of pre-Cambrian age was rendered perfectly clear by their position and by the finding of abundant fragments in the immediately overlying Cambrian conglomerates and breccias.

It seemed to me, therefore, probable that two distinct groups at least are represented in these western areas, and the microscopical examinations of these rocks which I have been able to make, with the valuable assistance of Mr T. Davies, has tended strongly to confirm these views. I believe, moreover, that there is a discordance in the strike of the two groups. The oldest of these—consisting of the massive hornblendic gneisses with a west-north-west strike (usually)—I would refer to the Lewisian group, whilst the more quartzose or granitoid types, with some associated schists, with a N.N.W. strike, I would refer to a newer group, and I see no reason at present why they may not be associated with the Dimetian, which of all groups at present known they most resemble.

As in Wales, so here the Cambrian conglomerates which rest upon these old rocks must be looked upon as offering most valuable evidence of the condition of things when they were deposited. They now rest almost horizontally upon the old floor, and the unevennesses of the surface of the latter are much as they were prior to the deposition of the overlying sediments, and are filled up usually by the latter. I noticed at once the generally more brecciated character here of these Cambrian sediments than in the majority of those in Wales; but, in both, the fragments are frequently so angular that I felt compelled to believe that some agent in addition to ordinary marine action had aided in heaping them up. In a former paper also I ventured to suggest ice as the probable agent, and more recently I find Prof. Geikie has suggested the same. These facts are interesting as indicating some of the physical conditions of the surface of the old pre-Cambrian land, and as I have shown in former papers that volcanoes also were studded over the surface, and that rain and river action was evident everywhere, we seem to be tolerably

able to arrive at some idea of its physical condition. That its gene surface was very similar to what might have been observed several succeeding epochs, and that the atmospheric conditions w also very much alike, seems highly probable. It appears to that the chief blank in the history still remaining is as to the st of vegetation and of animal life at the time. That such a la surface must have been covered by vegetation seems more th probable, and that animal life had attained to a high degree of p fection is clear from the abundance of life which we know to h existed in the surrounding Cambrian seas. The various fragme which make up these breccias and conglomerates tell us clea what rocks must then have occurred in that or some adjoining are and their condition. I have recently paid considerable attent to these fragments, and I find that they belong to several typ We have the older gneiss rocks frequently represented; but, in ad tion to these, some slaty and schistose masses, certainly very unl those usually associated with the older gneiss groups. For instan micaceous, talcose, chloritic and purplish slates and schists are fou such as hitherto have been looked upon as characteristic only groups supposed here to be newer than the conglomerates. That so of these may have been derived from rocks in intimate assoc tion with the older gneisses may be possible; but if so, then I h that most of the evidence hitherto relied upon to separate the called newer metamorphic rocks from the older is of no avail, will have to be given up. In addition to the above-mentioned fr ments, bits of granite, quartz-felsites, quartzite, quartz and jas also occur, though not so abundantly as in some of the We areas. This evidence, it appears to me, conclusively shows t rocks of the character of the fragments found in any of the joining areas may, and probably are, of pre-Cambrian age, if th is not very strong evidence to the contrary.

In the Geological Survey Maps, all the metamorphic rocks to east and south-east of a line extending from Loch Carron, by L Maree, to Loch Eribol are coloured as altered Silurian. In year 1878, after carefully examining some sections in these area arrived at the conclusion that many at least of these so-cal altered Silurian rocks were of pre-Cambrian age, and that th was no evidence whatever to show that they were, as suppos newer than the Cambrian conglomerates. I endeavoured to sh that in some places the supposed passage was due to a decept

overlap, and in others to faulted junctions. Moreover, I described numerous rocks from the central areas, to show that they differed in no particulars from many of the rocks found in the western areas immediately under the conglomerates. In the early part of this year I again visited some areas further south, in a line with those I had previously examined, and the results throughout were only confirmatory of my previous suppositions.

Some of these I purpose now referring to. The sections I had previously examined were in lines nearly E. and W. across Ross Shire, from the coast about Gaerloch and Torridon, by Loch Maree, to the mountains about Auchnansheen. The line I took this year was considerably further south, commencing in the mountains at the head of Loch Shiel in Inverness, by Loch Eil, to Fort William, and afterwards southward across the Grampians in two different directions.

Glen Finnan, Loch Shiel, to the Caledonian Canal.

From the descriptions which had been given by Sir R. Murchison and others of this line of section, I felt that no better one could be selected for testing the accuracy of my previous section referred to, from Loch Maree to Ben Fin, exactly due north of this line. I was, however, well aware that I should not meet here with the newer rocks found in the western portion of that section, and which had a strike from N.E. to S.W.; but I anticipated the probability of meeting with newer rocks further east, if, as I had suggested, the rocks of Ben Fin and to the South formed a portion of an axis of pre-Cambrian rocks, and in this I was not disappointed.

In the mountains at the head of Loch Shiel the rocks are mostly rather massive gneisses, and much like some of those described by Mr. Davies and myself in the "Geological Magazine" from Gaerloch and Ben Fin. I have submitted all the specimens collected to Mr. Davies, and he entirely confirms my diagnoses of them. They are true gneisses, in which the minerals are all intimately crystalline, and they contain two felspars, usually white, but frequently of a pink or reddish colour, sometimes two micas, the predominant one being biotite, a fair proportion of quartz, and some sphene and garnet. Alternating with these are some thick hornblende bands, with a

gneissose foliation, and containing usually a small proport mica, quartz and felspar, and an abundance of sphene and ga also black mica schists, and a gneiss in which there are lenticular masses of mica. Some of the beds are much cont but in the more massive ones the strike is clearly seen, and generally in a direction from about N.W. to S.E., and hence in ag ment with that prevailing in the true gneisses at Ben Fin and ir Western areas. At no point in this area did I find any which was not completely crystalline, and in walking over mountains towards Loch Eil I found the same strike prevaili and the same alternations of rocks as those above mentioned u I reached Glen Fionn. It is impossible to conceive that th rocks can be altered Cambrian and Silurian sediments, as sugges by Sir R. Murchison and Prof. Geikie, or that they can have b changed into this condition since Silurian times by any process selective metamorphism. Indeed, the evidence is now alm overwhelming that no such great changes have been produced any sedimentary rocks of great thickness, or occupying a la area, which have been deposited since pre-Cambrian times. maintain, therefore, that these rocks about Glen Shiel are doubtedly pre-Cambrian, and that they cannot in any way differentiated from the pre-Cambrian rocks along the west c about Gaerloch, either by their mineral or physical characte At Glen Fionn, at the head of Loch Eil, a mass of granit seen, apparently striking in a N.E. direction, and immedia beyond this, and reaching for some distance towards Fassfern, gneisses prevail. These differ considerably from those far west, and strike from N.E. to S.W. with an average of about 45° to the N.W. They alternate with a corrug mica-schist and with quartzose bands which are spotted a greenish micaceous mineral. These I look upon as n than the Loch Shiel series, and probably faulted down against

* In the excellent collection of rock specimens in the Jermyn S Museum, which I have had the pleasure of repeatedly examining, thr the kindness of Mr. Rutley, some good specimens of granitoid gne occur, labelled Strontian, Argyleshire. This place is nearly due Sout Loch Shiel, and it is evident that they belong to the same axis of Cambrian rocks. Others in the same Museum from Loch Duich show character further north. The specimens from these several points, w are all true gneisses, prove beyond doubt that there is a great t ness of such rocks repeated in folds running partially across the and that they are not a local development dependent upon some sp cause.

latter. They should probably be classed with the Pebidian rocks of Anglesea, and with others to be further referred to in the more central parts of Scotland. At Fassfern they are overlaid by quartz rocks, dipping at a very low angle to the S.E. The detrital origin of these is still most marked, and they may be said to be comparatively unaltered, though the fine admixture of quartz grains with bits of felspar may at first lead one to think that there had been considerable change. They seem here to occupy a depression similar to the one on the opposite side of the axis, and they may be, in my opinion, the equivalent beds to those found underlying the limestone at Glen Laggan, and which are found at several points along the west side to curve upwards, as at Loch Doule, Loch Carron, &c., to overlap the axis on that side. Between Fassfern and Kilmallie they bend round so as to dip to the N.W., and near the latter place again overlap some grey gneisses and mica schists. Some of these, as seen in a quarry on the roadside west of Kilmallie, appear to be a kind of talcose gneiss, but the majority are grey, highly micaceous, thin bedded gneisses and mica schists. I look upon them as forming a portion of the same series as those described between Glen Fionn and Fassfern. At Banavie, on the side of the Caledonian Canal, there is an exposure of a granitic rock, consisting of coarse-grained red felspar, chiefly orthoclase, quartz (sometimes in continuous bands) and a soft greenish micaceous mineral. This mass appears almost identical in character with that described in my previous paper (and more fully since by Mr. Davies in the "Geological Magazine") from Glen Laggan, Loch Maree. As there, also, its general strike is from N.E. to S.W., and the quartz bands seem also to arrange themselves in that direction, as in the case of the Glen Laggan mass, I look upon this as primarily an intrusive rock, but of pre-Cambrian age, and hence to be classed properly with rocks of that age. Along the line described some dykes of diorite were also met with.

Fort William and Glen Nevis.

Immediately under Fort William, and extending in a line from N.E. to S.W., chloritic schists and rather massive chloritic rocks are found. They dip at a high angle to the S.E., and attain in places a very considerable thickness. In the mountain to the S.E.

towards Glen Tarbet they are overlaid by quartz rocks, and these are succeeded by a black calcareous shale, which decomposes very readily where exposed, leaving on the surface some very beautiful crystals.* Resting on the latter are dark slates and shales, penetrated by dykes of a greenish grey felspar-porphyry. I was guided over this interesting section by Mr. Livingstone, of Fort William. A similar succession to that just described is met with also in Glen Nevis. The chloritic rocks, with some alternating bands of compact quartz rocks and quartzose schists, are found at the entrance, and these are succeeded by the quartzites towards Claggan, the calcareous shale and slaty series being well exposed in the hill S.W. of Glen Nevis House. Though the strike in the chloritic series is almost identical with that in the overlying shales, slates and quartz series, I yet believe that the latter rest unconformably upon the former, which, from their general appearance and their state of alteration, I am inclined to associate with rocks found in other areas in the Pebidian group of the pre-Cambrian rocks. I believe that there are some important faults also in this immediate neighbourhood which have somewhat interfered with the succession, for the newer beds are tilted up to an unusually high angle, and stand apparently endways, against the base of Ben Nevis.

Ballachulish, Glen Coe, and Black Mount.

In travelling along the road from Fort William to Ballachulish the chloritic rocks already mentioned are found to extend continuously to the entrance into Loch Leven. Here they are covered by a series of quartzites which dip at a low angle to the S.E., and these are again succeeded by slates and shales.

The section along the south side of Loch Leven is a most instructive one, and shows clearly that the Silurian rocks are here

* I have submitted this rock to Mr. Davies for examination, and he writes concerning it as follows:—"On prolonged digestion with acid the whole of the lime carbonate is broken up, the resulting rock being a soft muddy shale which is apparently somewhat carbonaceous, and contains much of a colourless talcose or micaceous mineral. The diverging blade-shaped crystals have been originally tremolite, but they are now wholly replaced by talc and a little calcite. I am inclined to think that the calcareous portion is not of subsequent introduction, as the shale, after the dissolution of the calcite, becomes soft and easily pulverizes between the fingers to an almost impalpable mud. It has not suffered much change [illegible]."

contained in two distinct basins. The section westward from the Ballachulish Hotel to the Ardsheal Peninsula has been carefully described by Prof. Harkness.* He describes the "syenite" as "flanked on the coast by metamorphic rocks in the form of quartz rocks and limestone. On the east of the Ardsheal Peninsula the syenite is seen forming the hill of Benivair, against which, on the west, there occurs a mass of quartz rocks, which, when in proximity to the syenite, contains crystals of felspar, and becomes almost a porphyry. . . . On its N.W. side it becomes more distinct in its stratification, and is succeeded by a grey limestone about twelve feet in thickness. Above this limestone the dark grey slates are seen dipping in the same direction, but on passing over the Ardsheal Peninsula the inclination of these slates becomes reversed. On the western side the quartz rocks again make their appearance, dipping under the slates, and these quartz rocks repose against another mass of syenite which forms the extreme west of the Ardsheal Peninsula." The above description shows clearly that we have here a true synclinal fold of the quartz rocks, limestone and slates. Prof. Harkness believed that the "syenite" here was an intrusive mass, and that it altered the overlying sandstones. From what I have already mentioned of the section at Loch Eil, it will be gathered that there is the possibility that, like the granite masses there, it is of pre-Cambrian age, and that the sandstones were really deposited upon it, and that the crystals of felspar mentioned in the quartz rocks were derived from the denudation of the granite. It is coloured as granite in Prof. Geikie's map, and it is described carefully by Mr. J. A. Phillips in the "Quart. Journ. Geol. Soc."† On examination I could find no evidence of its having produced alteration in the Silurian rocks, and the included masses so plentifully met with in it are fragments from the old gneiss group, being usually bits of gneiss with biotite and sphene. The sections along the shores of Loch Leven towards Glen Coe show that there is here another well marked synclinal fold. On the north shore between the Ferry and Onich the quartzites and succeeding beds are clearly seen, dipping to the S.E. for some distance, and eastward, opposite the Ballachulish slate quarries, the dip is reversed to the N.W. in the slates, and beneath these again in the quartzite group.

* "Quart. Journn. Geol. Soc.," Vol. xvii, p. 266.
† *Ibid*, Vol. xxxvi, p. 14.

On the south side a similar order is clearly traceable as we travel eastward from the Ballachulish Hotel, the dip at first being to the S.E., and afterwards reversed to the N.W. The slates here are not more highly altered than are some of the Arenig slates in Wales, and I was tempted to spend some time in searching for fossils, but, unfortunately, to no avail. Indeed, the whole of the rocks exhibited in this trough are so exceedingly like the lower Silurian rocks of Wales, that one is almost inclined to classify them with either the Arenig or Llandeilo groups. They have been traversed by numerous dykes of igneous rocks, and approach the great granitic masses, and yet we see no evidence of conversion into true gneiss rocks. How this fact is to be reconciled with the views held by Sir R. Murchison, Prof. Geikie, and others, that the whole of the metamorphic rocks in the North Western and Central Highlands, including true gneiss rocks, &c., are only altered Silurian rocks, I am quite unable to conceive. We have in these all kinds of detrital materials, from quartz, mica and felspar to mixtures of these with argillaceous deposits in very varying degrees, and yet there are no indications anywhere of conversion into gneiss. There are beds with alternating laminæ of various kinds of deposits, but these show no true change, and nothing approaching to that complete change or crystallisation throughout in all the minerals which is characteristic of true gneisses. On entering Glen Coe we lose the quartz rocks suddenly, as if they were faulted against or overlay unconformably the rocks which lie to the east, and occupy the glen. In the glen, as we ascend, we meet with numerous bands of dark green igneous rocks, probably basaltic lavas, some banded felsites, porphyries, and a granite like that at Ballachulish. Alternating with these are gneiss rocks and jaspery-looking bands. There are also some brecciated rocks. The whole group calls to mind the Arvonian rocks of North and South Wales, and the resemblance to these of some of the rocks is most remarkable. I think there can be no doubt that, after excluding some recent dykes, we have here a pre-Cambrian group of lavas, breccias, hälleflintas and gneiss rocks, upon which the Silurian rocks have been deposited unconformably. In the Black Mount area granites and gneisses prevail. The granite here is much like that met with at Banavie and along the Caledonian Canal, and again recalls strongly the granite of Glen Laggan, Loch Maree. It contains the same "large grained

crystalline association of quartz, and a reddish orthoclase with some microcline," and "the same greenish, soft and talc-like" mica. It is also frequently banded. In addition to the granite above described, other varieties are also met with—some large-grained with a white felspar, and some fine-grained of a light pinkish hue. There are also some granitoid gneisses, and a dark fine-grained moderately massive gneiss is very prevalent in association with the granites between the Black Mount and Loch Tullich. According to Murchison the gneiss is "occasionally hornblendic," and Nicol mentions along the same line, "gneiss, quartz rocks, and mica-slate, the last often containing hornblende crystals." All these beds are highly inclined and sometimes contorted. On the road between Loch Tullich and Tyndrum, near Orchy Bridge, an entirely different group of rocks is again met with. They are called by Murchison and Geikie "quartzose flagstones," and are stated to dip to the N.W. at an angle of 15°-25° here, and in the adjoining mountain of Ben Do at from 10°-15°, and afterwards to bend round so as to dip to the S.E. at a "higher angle than on the north-western side." It was impossible not to suspect at once in examining this area, and in tracing the continuous line exhibited by these sandstone beds from mountain to mountain to the N.E., that we had here a broken anticlinal of these rocks, and that the granites and gneisses of the Black Mount area and the rocks of Glen Coe formed the floor over which these had been deposited, and afterwards the axis over which they had been bent. We have, undoubtedly, here a great pre-Cambrian axis (though, as I shall further show, probably not the only one) in the Central Highlands, and it can be traced for a considerable distance to the S.W., as well as to the N.E. I examined it along Glen Spean and Loch Laggan to the N.E., and I there found the same granites and gneisses composing the axis, and the same flaggy sandstones dipping away from the axis, as described near Fort William and Loch Leven on the N.W. side, and in the range of mountains on the S.E. side. As the axis is traced to the N.E., it is quite evident that a greater breadth of pre-Cambrian rocks becomes gradually exposed, and the schistose series, characteristic, I believe, here of the Pebidian group, with crystalline limestone and serpentinous bands, prevails over a considerable area, and is well exposed along Glen Garry, Glen Tilt, &c. These schists have a strike almost identical with the Silurian rocks, and may therefore,

by physical evidence alone, be confounded with them. But as petrological evidence is capable of differentiating them, clear that they are entirely unlike in their state of alteratio in most of their mineral characters. I feel convinced, ther that all these must be included in the pre-Cambrian rocks that they are overlaid unconformably by the quartz rocks t S.E., these quartz rocks also being contemporaneous sedi with those at Schiehallien and in the line of mountains t S.W., including Benchalader and the mountains to the No Tyndrum.

Tyndrum to Cullender.

In the area immediately to the south and east of Tyndrun the pre-Cambrian rocks again appear uncovered by newer de Here they are chiefly mica schists, with a dull silvery lustr highly micaceous and quartzose gneisses. About Loch Do according to Murchison and Geikie,* they are much gnarle twisted, dipping in various directions from N.E. to S.E.

The gneisses and mica schists in this neighbourhood may t to resemble, in some respects, the Dimetian rocks of loch and Ben Fin, especially the thinner series in that They contain an abundance of garnets and the two micas, b biotite is generally in small proportions only. In a line fron towards the N.E. they are again plentifully exposed, and north bank of Loch Tay are interstratified with hornblende also exceedingly like those found at the Kerrie falls near Gaer Near Crianlarish and Luib, and also along Loch Tay band crystalline limestone occur "with numerous green serpen and talcose interlaminations." At first sight these much res the gneiss rocks, and are frequently much crumpled.

To the south of this line schistose and slaty chloritic become more abundant in association with micaceous and the mountains Ben More, Ben Voirlich, and Ben Ledi c largely of chloritic rocks in association with micaceous and gneisses. These may be well seen in the railway cut

* "Quart. Jour. Geol. Soc.," Vol. xvii., p. 218.

† Some specimens of the hornblende rocks from Loch Tay are to t in the Jermyn Street Museum, also gneisses from the Silurian, n Arroshan, Loch Lomond.

and along the roadside between Killin Station and Loch Lubnaig, and particularly in the mountain Ben Ledi, on the west of that lake. The rocks in the areas last mentioned everywhere strongly recall to mind the pre-Cambrian rocks of Wales, especially those in Anglesea and in the Lleyn promontory, which I have included amongst the Pebidian group. The hard, massive, and schistose chloritic rocks also strongly resemble many of the rocks in that formation at St. Davids, and as the strike in these and in their associated schists and gneiss is invariably the same, I think there can be no doubt that they should be grouped together in that formation. The tolerably persistent strike from N.E. to S.W., which coincides generally with that in the Cambrian and Silurian rocks, has undoubtedly here, as in Wales, caused these rocks to be allied with those deposits, and the petrological evidence has usually in consequence been entirely overlooked. Now that these have been separated by stratigraphical and petrological evidence in Wales, the time seems at hand when a similar attempt should be made in Scotland, and the results obtained by this recent examination of many areas in that country have fully convinced me that this is quite possible, and that it must ere long be accomplished.

Ireland.

Of late years but little has been done in Ireland to unravel the history of the metamorphic rocks, but I am glad to find that there is some tendency there at the present time to attack the question afresh. If the evidence I have brought forward in regard to the rocks which occupy most of the north-west Highlands of Scotland is in any way conclusive, then I think it will be readily granted that the rocks which have been by so many authors, including the members of the Geological Survey, correlated with them in the north-west of Ireland, may be treated by the same kind of evidence. From specimens I examined with Dr. Sterry Hunt, which he had received from Mr. Jas. Thomson, of Glasgow, from the intermediate islands, especially Islay, I have no hesitation in saying that the rocks are in every particular to be correlated with pre-Cambrian rocks from the west coast of Scotland and from Wales. Dr. Hunt also examined the rocks along the shores of Lough Foyle, and

these he correlates with the Huronian or Pebidian group. Hence, if these facts are taken in association with the former researches of Prof. Harkness, it seems to me impossible not to arrive at the conclusion that the metamorphic rocks along the north-west of Ireland must be of pre-Cambrian age. Recently an interesting communication by Mr. G. H. Kinahan, of the Geological Survey of Ireland, to "Nature," has tended much to strengthen these views. He does not actually place these rocks with the pre-Cambrian, but he says that the evidence goes to show that in the County Tyrone, "there are metamorphic rocks which were upturned, contorted and metamorphosed and denuded prior to the overlying fossiliferous 'Pomeroy rocks' having been deposited. The fossils in the latter would point to their being Cambro-Silurian." Considering that these had hitherto been classed with the so-called newer Metamorphic series, of supposed Silurian age, in Scotland, this fact, placed before us by Mr. Kinahan, is of the utmost importance. He mentions other areas also where these so-called newer metamorphic rocks underlie unaltered rocks with Cambro-Silurian fossils, as in north-west Mayo, and in south-east Wexford. I must confess, however, that in some of the other areas, where I also consider the metamorphic rocks to be chiefly of pre-Cambrian age, he still supposes them to be of later date—to have, in fact, been metamorphosed "at the close of Cambro-Silurian times"—and others "subsequent to the dawn of Upper Silurian times." It is, however, satisfactory to find it stated in his concluding remarks that "it seems possible the metamorphic action prior to Cambro-Silurian, may have been greater than that subsequent to it." This is really what I have maintained for so long a time, viz.: that metamorphic action on a large scale, and affecting great thicknesses of strata, has not taken place in the British areas since pre-Cambrian times.

In 1878 I examined in company with Dr. Sterry Hunt and others the metamorphic rocks along the coast of Dublin and Wicklow, and the unaltered Cambrian rocks in proximity to them. The metamorphic series are here intruded into by great masses of granite which send out many large veins, but these do not appear anywhere to pass into the neighbouring Cambrian rocks. If this is really the case, I cannot come to any other conclusion than that the metamorphic series and the intrusive granite are of pre-Cambrian age, and that the Lower Cambrian rocks of Bray

Head rest unconformably upon, or are perhaps partly fault against these, and, moreover, that they were derived chiefly fro the denudation of the metamorphic schists and granite.

It seems to me, therefore, that we have very strong evidence show that in Ireland, as in Scotland, and in England and Wale fragments of the old pre-Cambrian land are frequently expose and may readily be found, and that the rocks composing them ca be identified usually by their mineralogical and physical characte from the newer sediments which either surround them, lie upo them, or are entangled amongst them.

ORDINARY MEETING.

JANUARY 7TH, 1881.

W. H. HUDLESTON, Esq., M.A., F.G.S., F.C.S., Vice-Presiden in the Chair.

The donations to the Library since the previous meeting we announced as usual, and the donors received the thanks of t Association.

The following were elected Members of the Association :—

Henry T. Wakefield, Esq.; Henry Wordley, Esq.; and A. Roberts, Esq.

Messrs. Spratling and Braby were elected Auditors of the A counts for the year 1880. [The latter gentleman being unable serve, Mr. Cheadle subsequently took his place.]

The following paper was then read :—

ON THE ZONES OF THE CHALK.

By Prof. J. MORRIS, M.A., F.G.S.

ANNUAL GENERAL MEETING.

FEBRUARY 4TH, 1881.

PROF. T. RUPERT JONES, F.R.S., F.G.S., President, in the Chair.

The Honorary Secretary read the following :—

REPORT OF THE GENERAL COMMITTEE FOR THE YEAR 1880.

Your Committee report as follows :—

Members elected during 1880...	49
Deaths 2 ... Withdrawals 9	11
Increase	38

The census of the Association on January 1, 1881, was as follows :—

Honorary Members	16
Life Members	79
Old County Members	20
	115
Other Members	341
Total	456

It will be seen from the Balance-sheet that the finances of the Association are in a flourishing condition. As there is only a sum of £340 17s. 8d. invested in Consols against 79 Life Members, your Committee recommend that a further amount of £60 be similarly invested.

Your Committee have the pleasure of reporting the completion of Vol. vi. of the "Proceedings," which brings the record of the work of the Association to the end of the last Session, and they feel sure that the volume will be found both interesting and valuable to the members generally.

Amongst the eminent men who have contributed to its pages, it cannot be deemed invidious if mention is here made of Professor

Owen, who took great pains to furnish a most valuable communication, and drew some original figures for its illustration.

The Library has been largely made use of during the past year. Numerous donations have been received, chiefly from kindred societies, with whom we exchange publications. Dr. F. V. Hayden, of the United States, has, as usual, been one of the principal contributors.

Your thanks are again due to Mr. Litchfield for the valuable assistance he renders the Librarian on meeting nights.

During the past year the members of the Association have visited many Museums and Geological Collections, as the following list will show :—

Museum of Practical Geology, Jermyn Street, where F. W. Rudler, Esq., F.G.S., gave a demonstration on the principal Rock-forming Minerals.

British Museum, where Prof. Owen, C.B., LL.D., F.R.S., &c., gave a demonstration on Extinct Elephants.

Prof. Rupert Jones' Private Collection at Camberley.

The New Museum at Oxford, where Professor Prestwich conducted a large party over the Museum and pointed out many of the most important geological collections and specimens.

Mr. Parker's Private Collection at Oxford, where the members who took part in the Oxford Excursion had an opportunity of examining a large and fine collection of fossils from the formations in the vicinity.

Kew Gardens, where Sir Joseph D. Hooker, C.B., F.R.S., &c., conducted a large party of the members over the Gardens, and demonstrated on many plants living there those features of most interest to the geologist.

Maidstone Museum, where Prof. Morris and Mr. Bensted pointed out some of the more interesting specimens of that excellent collection of fossils of the neighbourhood, including many mammalian remains.

Bristol Museum, where Professor Sollas, the curator of the Museum, gave a demonstration to the members who took part in the Long Excursion on the very large collection of fossils of the neighbourhood therein contained.

The Excursions during the past year were numerously attended, and there can be no doubt that this is one of the features of the Association, the interest in which ever increases.

The well-attended Excursion to the Hampshire coast, favoured as it was with unusually fine weather, was fortunate in being conducted by Mr. Gardner, who has for so many years worked at this district, from which he has made such extensive collections of fossils, particularly of plant remains.

The Excursion to Oxford was made particularly interesting and

instructive by the able manner in which it was conducted by Mr. Parker, and by the diagrams, maps, and sections of that locality, which he had specially prepared and distributed among those who took part in it.

Nearly the whole work of conducting the Long Excursion at Bristol and the neighbourhood devolved upon Professor Sollas, ably assisted by Mr. Pass. With splendid weather, and amid scenery which, as stated in the Programme of the Excursion (in the drawing up of which your Committee had the invaluable aid of one who knows the district well—the President of the Geological Society), is "unequalled by sea or land," and, with plenty to instruct the Geologist, the interest of the Excursion never flagged.

The following is a list of the Excursions, with the names of the Directors and the principal formations at each locality :—

LOCALITIES.	DIRECTORS.	PRINCIPAL FORMATIONS.
Hampshire Coast, from Bournemouth to Highcliff.	J. S. Gardner, F.G.S.	Middle Bagshots.
Camberley and East Hampstead.	The President, Rev. A. Irving, F.G.S., and Capt. Cooper King, F G.S.	High-level Gravels of the Plateau and Valley Gravels; Upper, Middle, and Lower Bagshots.
Upnor.	W. Whitaker, B.A., F.G.S.	London Clay, Oldhaven Beds, Woolwich and Reading Beds, Thanet Sands, Chalk, &c.
Oxford.	Prof. Prestwich, M.A., F.R.S., F.G.S., &c., and Jas. Parker, M.A., F.G.S.	Shotover Iron Sands(Wealden Clay), Portland Rock and Sands, Kimmeridge Clay, Coral Rag, Lower Calc. Grit, and Oxford Clay.
Aylesbury.	W. H. Hudleston, M.A., F.G.S.	Neocomian, Portland, and Uppermost Kimmeridge Clay.
Richmond Hill and Wimbledon.	J. Logan Lobley, F.G.S.	High-level Gravels, Lower Bagshot and London Clay.
Croydon and Riddlesdown.	J. Logan Lobley, F.G.S.	Valley Gravels, Oldhaven Beds, Thanet Sands, and Chalk.
Redhill.	C. J. A. Meÿer, F.G.S.	Lower Greensand.

LOCALITIES.	DIRECTORS.	PRINCIPAL FORMATIONS.
Maidstone.	Prof. John Morris, M.A., F.G.S., and Mr. Bensted.	Drift Deposits, with Mammalian Remains, Upper Bands of Lower Greensand, Hythe Beds=Kentish Rag.
Leith Hill and Dorking.	Rev. A. Irving, B.A., B.Sc., F.G.S., and Dr. Maybury, F.G.S.	Lower Greensand, Weald Clay.
Bristol.	Prof. W. J. Sollas, M.A., F.G.S., F.R.S.E., &c., Mr. Pass, and Rev. H. H. Winwood, M.A., F.G.S.	Recent raised Beaches, Lias, Rhætic, Trias, Coal Measures, Carboniferous Limestone, Old Red Sandstone, Trap.

The thanks of the Association are especially due to the following for assistance and hospitality at the Excursions :—The President, Prof. Prestwich, M.A., F.R.S., F.G.S., &c.; Jas. Parker, M.A., F.G.S.; Mr. Bensted, and Dr. Matthew Adams at Maidstone; Prof. Sollas, F.G.S., &c.; and Mr. Pass.

The Meetings have been well attended during the year, when papers of much interest have been read and discussed.

The following is a list of the Papers read :—

On the Geological and other Causes that affect the distribution of the British Flora, by G. S. BOULGER, F.G.S., F.L.S.

On the Classification of Rocks, by Rev. J. F. BLAKE, M.A., F.G.S.

On the Classification of Rocks, by Prof. RENEVIER.

On the Psammolithic Formations comprising the Formations between the Kimmeridge Clay and the Gault, by Prof. H. G. SEELEY, F.R.S., F.L.S, &c.

On the Geological and Physical Features of the Bagshot District, by the PRESIDENT.

On the Fish Fauna of the Yorkshire Coal Field, by JAS. DAVIS, F.G.S., F.S.A.

On the Geology of the Bristol Area, by Prof. W. J. SOLLAS, M.A., F.G.S., F.R.S.E.

On the Geologists' Association: its Origin and Progress, by the PRESIDENT.

On some Recent Researches amongst the Pre-Cambrian Rocks of the British Isles, by Dr. H. HICKS, F.G.S.

On the expiration of the customary period of office, Professor T. Rupert Jones retires from the chair. Notwithstanding his duties as Professor of Geology at Sandhurst, he has given much

time and attention to the affairs of the Association, and has thus earned the hearty thanks of the members. He has long been one of the most valued contributors to your "Proceedings," and the coming of age of the Association afforded him a happy opportunity for giving from the chair an historical *résumé* of its origin and progress.

Your Committee have much pleasure in proposing Mr. Wilfrid H. Hudleston, M.A., F.G.S., F.C.S., as the next President. For many years Mr. Hudleston has been a member of this Association. As a constant attendant at our meetings, a valuable contributor to our "Proceedings," a frequent director of our excursions, and a former secretary, Mr. Hudleston has shown in the most earnest manner the interest he has always felt in the welfare of this Society. The Committee have therefore no hesitation in expressing their firm conviction that under Mr. Hudleston's auspices as President the Association will not only maintain its efficiency, but that its continued advance and prosperity will be fully assured.

It is with regret that your Committee have to announce the retirement of Mr. Lobley from the editorship of your "Proceedings," a post which he has filled with much advantage to the Association for the long period of ten years. To him belongs the credit of having commenced the periodical issue of these "Proceedings," and of having conducted through the press five out of the six published volumes. Upon these results the late Editor may look back with legitimate pride, and with a consciousness that he has earned the best thanks of this Association, with whose welfare and progress he is so thoroughly identified.

Your Committee esteem themselves fortunate in having secured a promise of the services of the Rev. J. F. Blake as the future Editor of your "Proceedings." The extensive range of that gentleman's geological and palæontological knowledge, in combination with his well-known literary ability, will doubtless recommend him to the Association as an extremely fit person to superintend the issue of its chief publication.

It is a matter for no small regret, in which your Committee feel sure that all the members will share, that the pressure of business compels Mr. Price to retire from the office of treasurer, which he has filled with so much advantage to the Association for several years. In recommending Mr. Lobley as his successor, your

BALANCE SHEET OF THE ASSOCIATION

For the Year ending December 31st, 1880.

Dr.

		£	s.	d.
To Balance, January 1st, 1880		40	3	0
,, Sale of Publications		2	9	2
,, January and July Dividends on £340 17s. 8d. *Consols*		10	0	4
,, Life Compositions		36	15	0
,, Entrance Fees	£21 5 0			
,, Annual Subscriptions	£159 9 0			
		180	14	0
		£270	1	6

Cr.

	£	s.	d.
By Printing and Illustrating "Proceedings"...	53	11	7
,, Miscellaneous Printing...	22	17	1
,, Library	11	9	6
,, Fire Insurance up to 25th Dec., 1881... ...	1	17	6
,, Posting and Addressing	18	10	5
,, Stationery	2	19	10
,, Gas, Attendance, and Miscellaneous Items	19	18	1
Balance carried forward	138	17	6
	£270	1	6

We have this day examined the Accounts of the Geologists' Association, and find the above Statement to be correct.

ROBERT WM. CHEADLE, F.G.S.,
WM. J. SPRATLING, B.Sc., F.G.S., } Auditors.

21st January, 1881.

Committee congratulate the Association on having an opportunity of retaining the services of a well-tried officer, henceforth to be exercised in a different department.

Your thanks are still due to the Council of University College for the continuance of their liberality in allowing us the use of their Library for our monthly meetings.

Your thanks are also due to the Microscopical Club for the continued use of their lamps at our annual meetings.

The Report of the General Committee was unanimously adopted as the Annual Report of the Association for the year 1880.

The President here announced as the result of the Ballot that the following has been duly elected :—

General Committee and Officers for the Year 1881.

President.

W. H. Hudleston, Esq., M.A., F.G.S., F.C.S.

Vice-Presidents.

Prof. T. Rupert Jones, F.R.S., F.G.S., &c.

Henry Woodward, Esq., LL.D., F.G.S., F.R.S., &c.

Prof. John Morris, M.A., F.G.S., &c.

J. Hopkinson, Esq., F.G.S., F.L.S., &c.

Treasurer.

J. Logan Lobley, Esq., F.G.S., F.R.G.S.

Secretary.

J. Foulerton, M.D., F.G.S.

Editor.

Rev. J. F. Blake, M.A., F.G.S.

Librarian.

Bernard B. Woodward, Esq., F.G.S.

Wm. Carruthers, Esq., F.R.S., F.G.S., F.L.S.

E. Swain, Esq., F.G.S.

R. W. Cheadle, Esq., F.G.S.

J. S. Gardner, Esq., F.G.S.

W. J. Spratling, Esq., B.Sc. Lond., F.G.S.

J. Drew. Esq., M.D., F.G.S.

W. Fawcett, Esq., B.Sc.

F. W. Rudler, Esq., F.G.S., M.A.I.

H. Hicks, Esq., M.D., F.G.S.

James Parker, Esq., F.G.S.

H. Goss, Esq., F.G.S., F.L.S.

F. G. H. Price, Esq., F.G.S., F.R.G.S., M.A.I.

The thanks of the meeting having been given to the retiring President, Treasurer and Editor, and Prof. T. Rupert Jones having vacated the chair, the meeting was made an Ordinary Meeting.

ORDINARY MEETING.

FEBRUARY 4TH, 1881.

W. H. HUDLESTON, Esq., M.A., F.G.S., &c., President, in the Chair.

The Donations to the Library since the previous meeting were announced, and the Donors received the thanks of the Association.

The following were elected Members of the Association :—

Jonathan E. Hull, Esq. ; Richard James Cook, Esq. ; George Dansfield Brown, Esq., M.R.C.S., F.L.S. ; and Edward Fagg, Esq.

Numerous specimens, microscopic and others, were exhibited, including some for distribution.

ORDINARY MEETING.

MARCH 4TH, 1881.

W. H. HUDLESTON, Esq., M.A., F.G.S., &c., President, in the Chair.

The donations to the Library were announced as usual, and the Donors thanked.

The President then alluded to the loss which the Association had recently experienced by the death of Professor Tennant, who had taken an active part in the management of its affairs during the first decade of its existence. Professor Tennant was the third President of the Association, and it would be found, on referring to the earlier numbers of the "Proceedings," that, both at that time and subsequently, he had been very active in directing excursions, giving lectures, and otherwise promoting the objects for which the Association had been founded. He was at all times interested in the welfare of the Association, and, though he had ceased for some years to participate actively in its management, yet even so recently as 1876, he assisted in auditing the accounts, and even to the last continued to manifest an interest in the conduct of its business.

The following were elected Members of the Association :—

H. Courtenay Luck, Esq., Assoc. Inst., C.E., F.R.M.S.; John Arthur Phillips, Esq., M. Inst., C.E., F.G.S., F.C.S.; Arthur Dixon, Esq.; Henry Nicholas Ridley, Esq.; Stuart Oliver Ridley, Esq.; Richard Edwards Bartlett, Esq.; R. A. Brady, Esq.; and Capt. H. M. Hughes.

The following papers were then read :—

1. "Remarks on a Proposed Classification of Rocks," by Prof. T. G. Bonney, M.A., F.R.S.

2. "On a New Theory of the Formation of Basalt," by the same author.

3. "Notes on the Microscopic Structure of the Basalts of Swallow Cliff and Uphill," by J. Slade, Esq., F.G.S.

Remarks on a Proposed Classification of Rocks.

By Prof. T. G. Bonney, M.A., F.R.S., F.G.S.

Few sciences appear so beset with difficulties, or at first sight so hopeless to the beginner, as Petrology. This is partly due to its inherent difficulties, partly to the mass of error or of uncertainty with which it has been encumbered by imperfect observation and too rapid generalization. In the present condition of things, as it seems to me, it becomes the duty of those who have devoted considerable pains and time to the study of the least remunerative branch (in a pecuniary sense) of geology, to insist upon what may be regarded as established, and to indicate the errors which stand a chance of being popularized.

The present state of the science of Petrology is this. The use of the microscope, and the indirect education which it has given to the eye of the observer, have enabled us to acquire a large number of facts about the mineral and other structures of rocks, and to obtain valuable materials for a system of classification. These have thrown much light on the association or paragenesis of minerals, have revealed the significance of many structures which was previously only conjectured; and have placed our feet in not a few cases on sure ground, instead of on the shifting quicksand of uncertainty. At the same time there are many problems left unsolved, or whose solution is not quite completed to the satisfaction of the more

cautious. For example, in the great majority of cases, we can certainly distinguish between an igneous and a metamorphic rock—but there are a few exceptional cases still remaining, where we do not yet feel quite sure what weight to assign to certain peculiarities of structure, and cannot venture to speak too confidently. As however difficulties have disappeared in the past, so probably they will vanish in the future; and in admitting that we have yet much to learn, we cannot justly be called upon to neglect all that we have ascertained, or to admit that the whole field is free to be the playground of all comers. No small part of the difficulties with which we are encumbered arise from the contradictory character of the statements which we find in our literature. Now, as regards these I will venture to remark (as I have already done more than once) that petrology cannot be studied either in the laboratory alone or in the field alone—the mere chemist, the mere student of microscopy, is no less liable to fall into error than the mere wielder of the hammer, who at most assists his eyes with a pocket lens. The petrologist, wherever it is possible, in every serious piece of work, should collect his own specimens in the field, should select the fragments for microscopic examination from the rock itself, and should test with the microscope the suggestions of the rock mass, and return again to the field to try the questions which the laboratory has formulated.

I purpose then, on the present occasion, to examine a classification recently published in the pages of your "Proceedings," by my friend Mr. Blake, with the view of showing that, instead of arranging "the newer facts . . . . in their logical places," and amending existing systems of classification, he has not, in my opinion, improved our position in any respect.

Now, as regards the classification of rocks, I must admit that I do not see any hope of a very rigid system, or one perfectly free from objection. Nature declines to draw hard and fast lines between the different species of rocks. At the same time we must classify, in some way or other, and must give names to the more conspicuous types. After all, the palæontologist is only in a better case than the petrologist, owing to the fortunate imperfection of his record. Some day or other, unless he prudently restrain the ardour of his collectors, he may find it very difficult to say where a species begins or ends in time and in space, or to settle what is a variety and what a species.

On what principle, then, are we to classify rocks. Some petrologists attribute great importance to the geological age of a rock, but this, I believe will, before long, be allowed to be quite inadmissible as a basis of classification. Some would adopt a classification purely chemical. This is obviously objectionable, because the history of the rock is almost wholly neglected, and thus igneous rocks and their derivatives may be associated. Most petrologists at the present day consider it best to separate rocks into groups dependent on their mode of formation, and then, as regards the igneous, to classify them primarily by their mineral constituents, and, secondarily by their crystalline condition; that is to say, to make the conspicuous presence of some one or more minerals the basis of what we may call our genera, and the crystalline condition of the rock—due no doubt in great part to the circumstances of cooling—the determiner of our species.

To this matter, however, I shall return after making some comments on Mr. Blake's criticisms on the classification of others, and on that proposed by himself. First, then, as regards his remarks on one furnished by myself to Mr. Jukes Browne for his School Manual of Geology. I think I have some right to complain of the way in which Mr. Blake has used this; the book was written for school boys, and the classification was confessedly an imperfect one. Only the commoner rocks were inserted to avoid puzzling the beginner, and it is stated by Mr. Jukes Browne that it is the "basis of one which I am about to employ in a forthcoming Manual."* Mr. Blake's words are, "which is stated to be that used in a Handbook of Petrology." Hence it is not only an "incomplete one," but is so intentionally and confessedly. No one would infer this from Mr. Blake's words. To this I may add that I fail to perceive the cogency of the following remark:—"Prof. Bonney's classification is an incomplete one, otherwise he would have to make a third subdivision of those which contain no felspar, and in this as in Prof. Dana's group vii., Mineralogy and Chemistry, would have to be fairly thrown to the winds." I am glad to learn this fact, for I had

* As Mr. Blake has alluded to the non-appearance of this Manual, I may as well say that I have abandoned the idea of publishing it. Owing to pressure of work either of a more imperative or more interesting character, I had not made much progress with it when Mr. Rutley's book appeared; for I found it needful to test the accuracy of so many statements, not wishing to write a mere compilation. On the appearance of this book I saw at once that the pecuniary success of my own contemplated larger work, dubious before, was hopeless now, and not reluctantly, as I must confess, abandoned the task.

always thought that the Peridotites made as good a natural group as any other. But perhaps Mr. Blake supposes that I should associate with these Peridotites Greisen, Tourmaline-rock, and the Eclogites—as I know some have done. Nothing of the kind. The first two belong to the metamorphic division; the third—often called 'the garnet-rocks'—will probably require a subdivision to itself, but until I have had the opportunity of studying it a little more in the field, I decline to express an opinion on this point. At present the evidence as to whether its members are igneous or not, is rather conflicting. I suspect, however, that the more typical eclogites will prove to be igneous, and their relation to be with the diorite group, garnet having taken the place of felspar.

Mr. Blake retains the term Trappean in his classification, but, after reading his remarks over several times, I confess that I fail to apprehend exactly what he means. The following paragraph (p. 418) at first sight appears to afford us a clue:—"It appears to me, however, that we require a name for those igneous rocks, which are intrusive in long sheets and dykes. Certain peculiarities appear to be involved in this mode of occurrence as in Pitchstone and in Felstone, but these peculiarities are capable also of production in rocks which have flowed as lava by a long process of devitrification. It is therefore improbable that any rock is exclusively a Trap rock, and the whole series may be represented also as belonging to the altered volcanic rocks, or in some cases to the Plutonic. Nevertheless, the name is a useful one in the sense defined, and may therefore be retained."

This, however, leaves one still perplexed. I did not know that the basalt of intrusive sheets and dykes differed in every case so materially from that of flows, or that pitchstone was a devitrified rock—though of course it can be devitrified—or that the pitchstone of Arran differed so materially from that of the Scur of Eigg. Mr. Blake does not tell us what he means by felstone; so, as I have always regarded the term as a very inclusive one, I cannot comment upon this part of his statement. To myself, however, the term Trap has long seemed absolutely valueless for any purpose of classification, and only useful, as a traveller's term, to express imperfect knowledge. In that sense I should not myself scruple to use it. So also such names as felstone, greenstone, greystone, are advantageous—being used by the petrologist much as the words "a monkey," "a cat," "a serpent," are by zoologists.

I proceed now to some minor but important details in Mr. Blake's

proposed table of classification. I utterly fail to understand why felsite, using the ordinarily received definition, should be put among the "altered (igneous) rocks," or differentiated from felstone (which I should have thought included it), and from elvanite* (which I suppose is quartz-felsite). Porphyrite is surely not identical with andesite.

I do not understand the complete separation of rhyolite from trachyte (unless it is meant to restrict this latter term to sanidine trachyte), and if so why domite (usually held to contain more of plagioclastic felspar, and to be somewhat altered) should be placed as a sub-species with sanidine trachyte under this head. What is the exact meaning of trachydolerite? I always thought it was a waiting room in which some andesites, phonolites, exceptional basalts, &c., were left for a time.

The following statement appears to me hardly correct :—" Pearlstone, or Perlite, has reference to a structure induced in the rock after its formation." Surely we may regard it as proved that this structure is produced while the rock is cooling.

Why are nephelinite and leucitophyr placed as sub-species to dolerite, and not also to basalt? Why is basalt, in the volcanic group, not to have a trachylite, and why is the latter rock among the traps? Why is phonolite under both? Why is eclogite among the "volcanic traps," whatever they may mean. As I have said, I would rather not speak too positively about eclogite, but this is almost the last place to which I should have assigned it? Why is lherzolite also placed here? I have examined the rock in the field, and cannot understand the motive. Mr. Blake's remark about the relations of minette, kersantite, and kersanton (between the last two there is no real difference) with syenite and diorite *may* be true, but I know of no evidence in favour of it, though these rocks have been well studied by me.

I cannot understand why luxullianite is placed among the granites, for, if ever there was an altered granite it is one; nor why serpentine, a rock practically without felspar, should be placed as the metamorphic representative of olivine-gabbro, a rock where

* Or the quartz-porphyry of many authors—a name which I think a bad one. I share Mr. Blake's objection to the term porphyrite, but regard it as now inevitable. Elvanite is a bad name for two reasons, first, a Cornish miner's name should not be given to a rock common all over the world, and second, different rocks occur in elvans. There are buff elvans (quartz-felsites) and blue elvans (diabases, &c.).

felspar makes up perhaps one-third of the whole. I should have thought that by this time there would have been accumulated proof enough to satisfy most people that the true serpentines are altered peridotites. Troktolite, or forellenstein, more nearly represents one form of olivine-gabbro, and the so-called saussurite-gabbro the rest. I may finally remark that Mr. Blake's classification (if intended to be at all complete) is defective. I do not find in it any peridotite except lherzolite, nor do I find greisen, or schalstein, or

ERRATA IN No. 2.

Page 100, line 21, for *trachylite* read *tachylite*.

Page 101, line 22, for *igneous* read *aqueous*.

in the case of granite) by extreme metamorphism. I do not indeed deny the possibility that any one of the igneous rocks *may* be a derivative rock melted down, but in that case all trace of its past history is lost—cast iron is cast iron, whether it has been obtained directly from the ore, or previously to its last melting, has been worked up a dozen times; but I do deny that any valid proof has

* Professor Renevier's classification, printed as the next article to Mr. Blake's, p. 426-8, also appears to me open to some objections, in the matter of the igneous and metamorphic rocks. I do not understand what is meant by Obsidian (trachytic), and Eurite (felsitic), amygdaloid, and Dioritic porphyry, as distinguished from Diorite, nor why Domite should be put with a (?) among Volcanic aggregates. The Leucite rocks and Nepheline basalts are, I suppose, included under basalts, and the Peridotites are wholly omitted. Why Granite and Syenite should be among his Cryptogenous or Crystalline, and not Diorite, perplexes me, as well as what Felsite is doing with Gneiss and Mica Schist. Serpentine, also, is not properly classed with the magnesian schists.

felspar makes up: perhaps one-third of the whole. I should have thought that by this time there would have been accumulated proof enough to satisfy most people that the true serpentines are altered peridotites. Troktolite, or forellenstein, more nearly represents one form of olivine-gabbro, and the so-called saussurite-gabbro the rest. I may finally remark that Mr. Blake's classification (if intended to be at all complete) is defective. I do not find in it any peridotite except lherzolite, nor do I find greisen, or schalstein, or the chiastolite, andalusite, and allied schists. We have quartz-syenite, but not quartz-diorite (or tonalite), and no tourmaline rock, except luxullianite. In short, the classification seems to me to be anything but logical.*

In conclusion, then, I will make a few remarks upon the principles which, in common with many other petrologists, I should adopt in classification. My first distinction would practically be an historical one, and have regard to origin, so that I should divide rocks into igneous and derivative—the former being presumably part of the original material of the globe, the latter the result of the destruction of some portion of this. First among these, and in close connection with the former, would be the pyroclastic rocks, the agglomerates, ashes, tuffs, &c.; then would come the rocks commonly called igneous; then those precipitated from a state of solution; and then those formed by the intervention of organisms. For each one of these there would be a possible metamorphic equivalent. In this classification, it will be observed, I tacitly repudiate any reversion of the derivative into the igneous rocks (often asserted in the case of granite) by extreme metamorphism. I do not indeed deny the possibility that any one of the igneous rocks *may* be a derivative rock melted down, but in that case all trace of its past history is lost—cast iron is cast iron, whether it has been obtained directly from the ore, or previously to its last melting, has been worked up a dozen times; but I do deny that any valid proof has

* Professor Renevier's classification, printed as the next article to Mr. Blake's, p. 426-8, also appears to me open to some objections, in the matter of the igneous and metamorphic rocks. I do not understand what is meant by Obsidian (trachytic), and Eurite (felsitic), amygdaloid, and Dioritic porphyry, as distinguished from Diorite, nor why Domite should be put with a (?) among Volcanic aggregates. The Leucite rocks and Nepheline basalts are, I suppose, included under basalts, and the Peridotites are wholly omitted. Why Granite and Syenite should be among his Cryptogenous or Crystalline, and not Diorite, perplexes me, as well as what Felsite is doing with Gneiss and Mica Schist. Serpentine, also, is not properly classed with the magnesian schists.

yet been advanced that gneiss passes into granite, and maintain that it is illogical to claim granite as a metamorphic rock, and not, at any rate, syenite and diorite. I know perfectly well that these transitions of metamorphic into igneous rocks have been repeatedly asserted to occur, but in the majority of these cases the statement rests upon the authority of the unaided eye, and that often of an ill-qualified observer. I have made it my business to examine (patiently I hope, and without prejudice) several of these asserted transitions, and have found, in every case, either that there is no evidence of it at all—that a knoll of igneous and a knoll of sedimentary rock cropped up from the grass within a few feet of each other has been evidence enough for some observers ; or that the alleged igneous rock is not igneous ; or that there is direct evidence to the contrary. Seeing then that there are a vast number of cases in which granite is as obviously an intrusive igneous rock as trachyte may be, and at best there are only a few where there is even obscure and defective evidence of gradual transition ; it appears to me that the whole *onus probandi* lies on those who assert the metamorphic origin of granite, and that very clear proof may reasonably be demanded.

Confining, then, our attention to the igneous rocks, upon what principle are we to classify them ? I confess that though it is not free from objection, I see none better than one resting upon mineralogy and chemistry. If, then, we adopt this, what mineral or minerals are we to select as of primary value for this purpose ? I must say that I can see none better than the felspar group and its allies. Mica is obviously useless, quartz and olivine alone are insufficient. Augite and hornblende indeed appear more promising, but then there seems no doubt that occasionally, whatever may be the explanation, they are paragenetic, and that the latter has often been produced from the former by paramorphic and other changes. There are undoubtedly two difficulties in the employment of the felspars (with the allied minerals, nepheline and leucite), the one the existence of microcline, a triclinic form of potash felspar—the other, that of distinguishing the various plagioclastic felspars—albite, oligoclase, labradorite, and anorthite—one from another. As regards the first difficulty, to which pre-eminence is given by Mr. Blake, I do not think it serious. So far as the crystallography goes, the deviations of microcline from orthoclase appears to be but slight (a cleavage angle of $90^{\circ}{\cdot}16$ instead of 90°), and it is so constantly

associated with intercrystallized albite, that one cannot help suspecting that it may have no more claims to be regarded as a separate species than perthite. Its mode of occurrence also is peculiar. The strong argument in its favour is its alleged optical characteristic, as set forth by M. Descloiseaux, in his elaborate memoir on the felspars.* But then we must remember that the constancy of these and their value in the determination of species have been denied after experiment by another competent observer. I cannot say that I have been very successful myself in obtaining satisfactory results from these tests. It may be then, that (omitting baryta felspar) there are but three distinct species—orthoclase, albite and anorthite; and that oligoclase and labradorite are, in some way or other, only paragenetic mixtures of these. Be this as it may, I do not see that the apparently restricted occurrence of microcline (even if it be truly a dimorphic form of potash felspar, is a bar to our using orthoclase (and sanidine) for distinctive purposes. At any rate, we seem entitled to assert that (as we should expect) free quartz is associated with the highly silicated felspars, especially with orthoclase, and mica and hornblende are more common with these; while olivine is generally associated with the others, and augite is much more common. Quartz, then, and olivine appear to form two ends of a chain, between which the other minerals may be fairly well grouped.

We come next to our secondary classification, or to the subdivisions of each mineral group, and here I can see none better than structure. I cannot admit the date of the rock as a basis of classification, notwithstanding there are some arguments in its favour, such as the restriction of leucite, so far as we know, to rocks of Tertiary age. The division into Volcanic, Trappean, and Plutonic is better, but it is open to the objection that the middle term was founded on an error (the most typical traps being now in many cases known to be ancient subaërial flows of lava), and that it seems impossible, away from the field, to distinguish some members of the Trappean group from Volcanic, and others from Plutonic rocks. Crystalline structure, however, is the result of the circumstances under which the rock has cooled. It can in general be readily recognised, and so affords a convenient method of distinguishing our species or leading varieties. There is, however, at present one

* "Annales de Chimie et de Physique," iv., 240, 1875.

difficulty which it is only fair to admit: the "semicrystallin division includes, at present, two marked varieties—rocks where t matrix is cryptocrystalline, and those where it is microcrystalli The former, no doubt, is sometimes the result of devitrificati i.e., of a secondary change. Is it always so, and if not, can distinguish those where it is a secondary change from those wh it is an original condition? and ought we not to separate the cry tocrystalline from the microcrystalline group? To these questi we cannot at present give an answer, but I see no reason why, w patience and labour, we should not ultimately be able so to do. any rate, this method of division seems to me to be more mana able and open to fewer objections than any other.

Each rock, then, of a given chemical constitution may occur, probably does occur, in each of these three conditions, glassy, se crystalline, and crystalline; but we shall notice that, as might expected, the glassy and semicrystalline varieties occur more co monly and in larger masses among the acid than among the ba rocks. Some readjustment of names will be required by th notably in the case of dolerite and basalt—the latter often be under the microscope, as truly crystalline as the former. The p nolites must be subdivided, and all the nepheline and leucite ro revised. The peridotite group also, as materials accumulate, m be more carefully studied. Still, though there are at present no few difficulties, and there always will be some, because nature her refuses to be fettered, I believe that the system of classifying p marily by composition, and secondarily by structure, is far bet than any other which has yet been devised.

On a New Theory of the Formation of Basalt.

By Prof. T. G. Bonney, M.A., F.R.S., F.G.S., &c

In this paper I propose to examine a theory advanced by Mr. T. Clough in a communication to the "Geological Magazine" October last (Dec. II, Vol. vii, p. 433), entitled "The Whin of Teesdale as an Assimilator of the Surrounding Beds." T theory seems to me so improbable, and so opposed to what I reg as established facts in petrology, that I cannot refrain from c cising it, though always an unwelcome task. I know, howe

from past experience that upon some geologists any theory of the metamorphic origin of rocks commonly called igneous exercises a species of fascination, and thus, if unchallenged, it is certain to find its way into text books and to add to the mental confusion of unhappy students of a subject already difficult enough. I have not, indeed, had the opportunity of examining the Whin Sill in the field, though specimens from it and the adjoining rocks have passed under my notice, but I have paid especial attention to the contact phenomena of igneous rocks, and particularly of dolerite and basalt, so that on this occasion I venture to depart from my usual practice of visiting a district before I write upon its petrology. I trust, then, to be able to show that the direct arguments advanced by the author in favour of his theory are inconclusive, and that it is so contrary to all we can learn from other quarters as to require the most indisputable proof before we are justified in accepting it.

For a brief enunciation of this theory I will quote the author's own words: "It seems to me that we shall be forced to conclude that the Whin consists in part of altered sedimentary beds; that it partly represents beds which were once in the position it now occupies; that it did not make room for itself simply by thrusting aside these beds, but also by incorporating them into itself" (p. 434).

The author's arguments may be classified as follows:—

(1) Field evidence in favour of his view.

(2) Corroborative evidence from other districts.

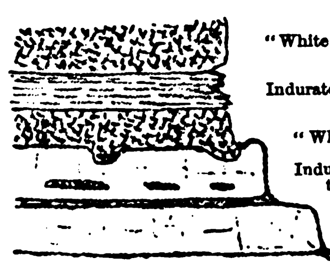
(3) Consideration of objections.

These I propose to deal with separately, before enumerating the facts which appear to me diametrically opposed to it.

(1) The cases instanced by Mr. Clough, though, no doubt, curious, do not seem to me at all conclusive in favour of his view. There is, he says, "a general absence of mechanical disturbance" of the surrounding beds; that is, the beds end abruptly against the Whin without any evidence of disturbance, such as faulting, bending down towards the intrusive mass, &c. He admits, however, that commonly the "Sill" is not seen included between the beds through which it has broken; and I cannot see that those cases which perplex him differ materially from many that I have observed, where it is hardly possible to assume a theory of assimilation.

For example, let us take the case of the vertical dykes of Strathairn* (Skye). Any one who has studied these in the field will, I think, admit that any assimilation theory is inadmissible. The basalt has broken through only slightly altered sedimentary beds in an almost countless number of dykes, generally a very few feet wide. The explanation seems to me simple—a great mass of basalt making its way to the surface has uplifted the overlying beds into a very low arch. These, unable to undergo much lateral tension, have cracked into a number of fragments like the separate blocks in a paved floor, and the basalt has welled up through the intervals. Now, it does not follow that these cracks should in all cases be vertical—even here they are not always so; but still in any case the cracks would gape in the same way, and there need not be any great mechanical disturbance of the ruptured strata. Basalt is seen in other parts of the coast to occur as intrusive sheets between the jurassic strata without much disturbance; yet in these comparatively modern deposits we can hardly expect assimilation, as there is no evidence of the adjacent beds having been long kept at a high temperature. The annexed diagram (Fig. 1) from a quarry

FIG. 1. BASALT INTRUSIVE IN THE CALCIFEROUS SANDSTONE SERIES W. OF BURNTISLAND HARBOUR.

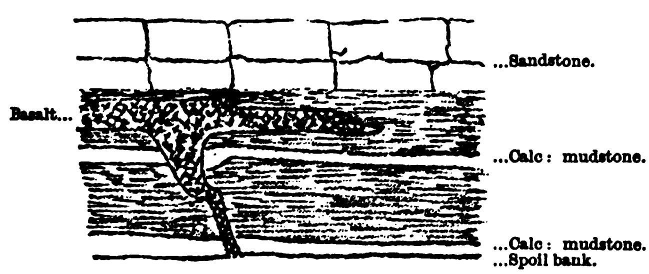


near Burntisland shows how a mass of basalt can inject itself without materially disturbing the adjacent beds. Perhaps Mr. Clough will say that in this case also assimilation has taken place. I can only reply that the boundary of the basalt (now in the condition of "white trap") is perfectly sharp, even where the sheet is no thicker than the hand; that the adjacent rock is but little altered,

* Figured by Macculloch. Western Isles, Pl. xvi.

so that the basalt cannot have been at a very high temperature; and that there is no reason to suppose the conversion of the basalt into white trap is due to any assimilation. The shale into which the basalt intrudes is a little squeezed and indurated—that is all. But when we consider that very probably all these rocks were more plastic and moist when the basalt was injected than they now are, it is easy to understand that the basalt might be compressed—as paper is in a bound book or textile goods packed by a Bramah press —without any conspicuous indication of the squeezing. The second diagram (Fig. 2) gives another instance, where compression is more

FIG. 2. BASALT INTRUSIVE IN CALCIFEROUS SANDSTONE SERIES, WHINNYHILL, NEAR BURNTISLAND (FIFE).



distinctly marked. I grant that I have sometimes seen instances where it was difficult to understand exactly how the rocks had been displaced, but we must remember that generally we have to explain the disturbances in a solid mass from a single plane section, and, therefore, need not be surprised at occasional difficulties, so long as we meet with numerous cases where the process is perfectly obvious.

Mr. Clough's strongest piece of evidence seems to me inconclusive. "Fortunately," he says, "we have in a few places much more distinct evidence than mere absence of disturbance to show that certain beds have been absorbed by the Whin. Here are a few sections which show at once the bottom and top of the Whin and the beds above and below, and so clearly that we may with certainty recognise these beds, and we can see in such cases that certain beds are missing where the Whin now is" (p. 437). The "best sections" are Cockle Syke, Rowantree Syke, and Lodge Gill Syke. The first two of these (400 feet apart) Mr. Clough

gives in detail,* pointing out that in the first two there is about 80 feet interval between two marked beds, in the one without any Whin, in the other, the same, including 21 feet of Whin. The coincidence is curious, but then to complete the proof we ought to find that the intervening beds also should be in part identifiable, which they are not. Is it not more probable that there is a thinning out? This, at the rate of 1 in 20, might easily be overlooked in the field where the intervening section is not well exposed. Mr. Clough says the evidence in Lodge Gill Syke is less conclusive, but I may remark that it at any rate proves the variability of the beds.

(2) As regards the corroborative evidence, this, on Mr. Clough's own showing, is not very strong where it does not rest upon insufficient authority. The basaltic rock will be found to lie amongst beds which are readily compressible, as mentioned above, or are easily reduced in volume, as coal. One case "of assimilating power derived from dykes," which is subsequently quoted, I have myself seen, and cannot admit the accuracy of the statement.

(3) I pass now to Mr. Clough's consideration of objections. To the obvious one that the Whin Sill is a normal dolerite or basalt, and thus shows no sign of that variation which we might expect in a rock which had digested at one place a sandstone, at another a shale, at a third a limestone, he replies: "There may have been a very general circulation, both on a large scale and molecule by molecule, reducing all the parts of the mixture to a uniformity of composition. The very possibility of forming alloys, and of modifying the properties of metals by adding to them small portions of other substances, depends on this principle of circulation or diffusion." The last remark is doubtless true, and the argument might be urged if we were dealing with a great mass of igneous rock which had for a long time remained at a very high temperature, but I think the analogy wholly fails here.

* This is Mr. Clough's section in ascending order:—

Cockle Syke.	*Rowantree Syke.*
a. Limestone.	*a.* Limestone.
80ft. shale, with occasional girdle beds; 4in. coal at top.	3ft. calcareous shale.
3ft. shale, with girdle beds.	14ft. altered shale.
14ft. sandstone.	21ft. Whin.
80ft. strong sandstone seen near the top; signs of a little limestone coming in about 12ft. from the top.	25ft. strong sandstone rests apparently directly on the Whin, then strong girdle beds and sandstone; no shale.
b. Limestone.	5ft. limestone.
	12ft. sandstone, thin flags in places.
	b. Limestone.

The rock in contact with the sill has evidently had its temperature locally raised by heat derived from the intruder. The latter, then, must soon have assumed a viscous condition, as is usual in flowing lava, and this would be unfavourable to diffusion. We must also remember that the volume of the basalt is supposed to be about equal to that of the missing rock, so that the basalt-making fluid must either have borne only a small proportion to the digested matter or have been little better than impregnated water. In the former case it would soon have lost its heat; in the latter we may fairly ask the author to give us some parallel of the existence of this "universal solvent" among known natural substances.

Mr. Clough attempts to strengthen his argument by estimating from analyses the mean composition of the various rocks which the basalt seems to replace. I confess that to myself the result, when compared with those given of the Sill itself, only increases the difficulty.* The solvent fluid must have contained alumina,

* The following are the analyses of a specimen of Whin (I.) from Tinkler's Syke, (II.) from Towards Bridge:—

	I.		II.	
Silica		51·47		50·35
Alumina		16·48		16·80
Protoxide of Iron		8·49		8·36
Peroxide of Iron		3·61		3·51
Protoxide of Manganese		0·46		0·41
Lime		8·22		9·01
Magnesia		5·10		5·73
Potash		3·28		2·87
Soda		1·18		1·07
Iron	0·08 } Iron		0·037 } Iron Pyrites	
Sulphur	0·09 } Pyrites	0·17	0·043 }	0·08
Water { Hygroscopic	0·50		1·20	
Water { Combined	1·20	1·70	0.80	2·00
		100·16		100·19
Specific Gravity		2·82		2·84

The following is the estimated analysis of the average sedimentary rock:—

Silica	48·206
Alumina	9·835
Iron Protoxide	1·832
Iron Peroxide	·612
Protoxide of Manganese	·042
Lime	19·332
Magnesia	·957
Potash	1·188
Soda	·117
Water	2·883
Phosphoric Acid	0·36
Organic Matter	·116
Carbonic Acid	15·477
Sulphuric Acid	0·66

And should be of specific gravity 2·62.

iron, and magnesia, as all these are notably deficient in the mean rock, and it must have had the power of disposing of a considerable quantity of lime, as this is in excess. Perhaps Mr. Clough will instance the cases of greisen, zwitter-rock, and tourmaline-rock, but in none of these is there anything like a complete melting down, only a metamorphism (commonly very local) of a portion of the constituents by hydro-thermal agency; the contact phenomena also are very different.*

I proceed next to consider the evidence adverse to Mr. Clough's theory, by propounding the question, "Do igneous rocks, as a rule, exhibit any indication of possessing this assimilating power?" I do not, indeed, deny the possibility of such a thing happening at very great depths; there, no doubt, by the action of heat, water, and pressure, sedimentary beds *may* be melted down and mingled so as to be indistinguishable from igneous rocks. But still I assert that such evidence as we have obtained is opposed to it where the rock is making its way upwards through sedimentary strata. Now, we should expect to find the best indications in the case of the coarsely crystalline rocks, because it is probable that they and the adjacent rocks have been kept for a long time at a high temperature. It is, I think, needless to describe in detail the cases with which my note-books are filled; a simple enumeration will suffice. I have, then, repeatedly seen fragments of schists and quartzites in granites (Scotland, Cornwall, Auvergne, and many parts of the Alps), and in gabbro (Cornwall), and have examined the junction surfaces of these rocks with these granites and with syenites and diorites.† Of these I have seen scores of instances where the junction-surface, as a rule, is perfectly clear and well defined, even under the microscope. A later granite or gabbro does not appear to melt down an earlier one through which it breaks, nor do gabbros nor granites appear to assimilate serpentine.

* I cannot believe it possible that angular fragments with perfectly sharp boundaries (even under the microscope) can be undigested residues. Mr. Clough quotes my lamented friend, Mr. Clifton Ward, as favourable to the view that an altered rock may have a sharply-defined margin. After a fairly large experience, I can only say that I have seen nothing to favour and much to oppose this idea, and, after examining the country, which he so admirably described, was unable to admit that there was any valid evidence for his view, and felt that in this one case even he was unable to free himself from that confluent metamorphism which seems so infectious among the members of the English Geological Survey.

† I have omitted serpentine because, perhaps, some geologists would still dispute its being an altered peridotite.

In short, among the coarsely crystalline rocks I have never had the least reason to suspect anything more than the slightest possible amount of surface fusion or welding. Regional metamorphism there may have been, but I speak now of contact effects.

Proceeding, then, to the finer-grained dolerites and basalts: I have examined intrusions of these into rocks of like nature, and into granite, syenite, gabbro, serpentine and felstone, often without the slightest indication of melting or of more than at most a mere surface fusion, if, indeed, it deserves that name. For instance, the dolerite of Salisbury Craig does not show the slightest sign of having eaten up the beds through which it breaks. Dolerites and basalts may be seen in numerous cases on the Fifeshire coast at various places, breaking through shales, sandstones, and limestones with perfectly clear, sharp, well-defined junctions, frequently including fragments of these rocks, sometimes in abundance. Near St. Monance a basalt is full of fragments of a rather coarser basalt, very much as a diorite (?) mass near Christiania is crowded with pieces of gneiss.* The columnar basalt of the Gross Weilberg (Siebengebirge) abounds in fragments (often about the size of a walnut) of the trachytic tuff into which it has intruded, and has been unable to assimilate. In all cases the included fragments, though more or less altered, like the surfaces of the same rock at a junction, retain much of their original character, and are rather "baked" or "stewed" than fused. But it is needless to continue to multiply instances.† I have studied the demeanour of igneous rocks near their junctions in hundreds of instances, and in many districts—as, for example, in Cornwall, Wales, the Lake District, Fifeshire, and other parts of Scotland, in our own island: in Auvergne, the Pyrenees, the Bernina Group, the Fassa Valley, and elsewhere in the Alps, and in various parts of Germany and Italy, without seeing anything to confirm, and much to disprove, this idea of a possible assimilation of sedimentary beds by a solvent mass, which has subsequently crystallised so as to be indistinguishable, even in its microscopic structure and chemical composition, from ordinary dolerite or basalt.

* Lyell's "Elements of Geology," p. 683. I have seen the place myself.

† I may venture to predict that when Mr. Clough has worked for a few years with the microscope at rock structure generally, he will be convinced that even a moderate-sized grain of quartz requires nature to use a very strong "gastric juice" in order to digest it.

Notes on the Microscopic Structure of the Basalt of Swallow Cliff and Uphill.

By J. Slade, Esq., F.G.S.

Swallow Cliff, visited by the Association in August, 1880, is a headland of carboniferous limestone, jutting out some hundred yards in the Bristol Channel, about three miles north of Weston-super-Mare. It rises perpendicularly on the north side to about 60 feet above sea level, and on the south side slopes to the water level at a sharp angle.

At a point on the north side near where it joins the mainland, and on the beach is a mass of basalt apparently interbedded, but very much weathered and broken into by the action of the sea.

Hand specimens of this rock have all the appearance of an altered basalt, being dense, amorphous, red in colour, with here and there rounded grains. Thin slices suitable for satisfactory observation under the microscope are difficult to make, but when made confirm this conclusion—all the original constituents are completely changed, except as to form, and of this barely sufficient remains for identification.

Thus this is a case in which the history of the rock can only be established by the use of the microscope, and chemical analysis would certainly prove fallacious.

A basalt is defined to be an igneous rock containing as essential constituents a triclinic felspar, augite, magnetite or titaniferous iron, and as frequently present, but non-essential constituents, olivine, apatite, and other minerals. We have here the result of replacement in such a rock, the augite preserving unmistakably its well known form, the felspar not so clear, but still to be obscurely traced, the [magnetite mostly converted into limonite, staining the rock throughout, and also into hæmatite; whether a glassy or amorphous magna was ever present, there is scarcely any evidence. Olivine grains were abundant, their external forms being distinct, though internally they are broken up into a honey-comb mass, with specks of magnetite passing into hæmatite.

The present condition of this rock agrees in a general way fairly well with the Toadstone of Derbyshire, and at one time no doubt they were identical, but there is an absence here of the chloritic minerals so abundant in that.

The polariscope reveals the existence of circular patches of acicular crystals probably of zeolitic minerals scattered at intervals, but calcite is not so constant as might be expected.

The basalt at Uphill seems to be the same rock but more metamorphosed and consequently more difficult to determine.

Some may call these basalts melaphyres, and so they are, but as they once agreed in composition with the basalts of mesozoic and tertiary age, the term appears superfluous.

VISIT TO THE BRITISH MUSEUM.

MARCH 12TH, 1881.

(DEMONSTRATION OF FOSSIL CORALS).

Director:—STUART O. RIDLEY, ESQ., B.A., F.L.S.

(*Report by* THE DIRECTOR.)

The Director met the members in the Natural History Galleries of the British Museum, in Great Russell Street, and pointed out the leading characters of the three chief groups of recent corals, viz.: ALCYONARIA, ZOANTHARIA, and HYDROCORALLINÆ, and of the lesser groups into which these may be divided. He called special attention to *Pennatula*, the *Gorgoniidæ*, *Paragorgia*, *Corallum*, and *Heliopora* among the ALCYONARIA; to the complex calicle of *Caryophyllia*, to the colonial *Astræidæ*, including *Mæandrina*, and to *Fungia*, *Porites*, and *Madrepora* among the ZOANTHARIA.

The HYDROCORALLINÆ were seen to be represented by but a small number of genera in recent seas, the chief types being *Sporadopora* (of which an enlarged diagram was shown), *Errina*, *Stylaster*, *Distichopora*, *Cryptohelia* (the latter remarkable for a small plate overhanging the mouth of the calicles, recalling the extinct *Goniophyllum*). Their position among the HYDROZOA was commented on.

In the "Challenger" collection of Deep-Sea Madreporaria, and Stylasteridan Corals, some Zoantharian forms were pointed out, which deviate from the usual rule of a sexradiate arrangement of the parts of the calicle, and the identity of some of the species with those of Tertiary deposits was noticed.

VISIT TO THE MUSEUM OF PRACTICAL GEOLOGY.

SATURDAY, MARCH 26TH.

(DEMONSTRATION ON THE ROCK COLLECTION.)

Director:—FRANK RUTLEY, ESQ., F.G.S.

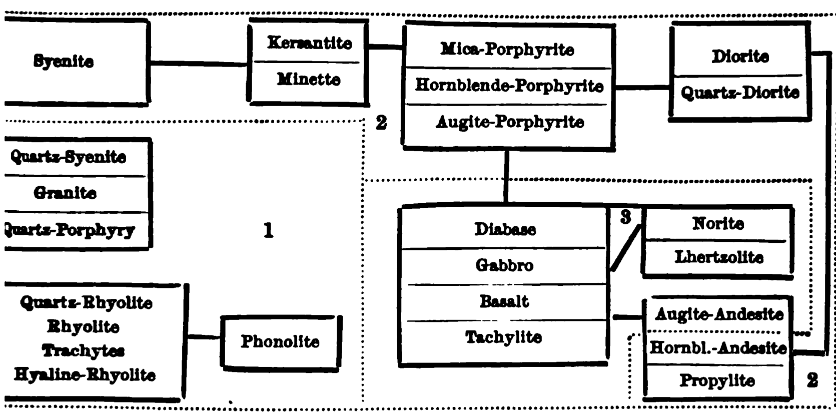
The arrangement in this collection, as pointed out by the Director, is stratigraphical as well as topographical, and in no way based on mineral constitution. The eruptive rocks will eventually be distinguished by red labels.

Particular attention was drawn to the rocks of the Lake District (Silurian). The micaceous dykes of portions of this country are noteworthy. The chiastolite slate which intervenes between the granite and the ordinary Skiddaw slate was pointed out. An extensive series of lavas, frequently containing very fresh augite, together with triclinic felspar and orthoclase, holds a position intermediate between the dolerites and the trachytes. Here also is observed a large series of fragmental volcanic rocks—some undoubtedly ashes, and others whose origin is not so obvious.

Amongst Devonian rocks, as developed in England, were shown basaltic lavas from the neighbourhood of Tavistock, and specimens of the Brent Tor lavas, breccias, and volcanic bombs. Allusion was also made to the extensive decomposition and replacement of matter in the schistose ashes of this region. The Dunstones of Devon are represented by old lavas and schistose tuffs. The remainder of the rock collection is arranged stratigraphically, but there is a case reserved to illustrate the general principles of petrographical science.

The Director afterwards proceeded to describe the method of preparing sections of rocks for microscopic examination, and subsequently indicated, with the aid of diagrams and drawings on the black board, some of the means for the determination of the minerals by optical characters. He more especially dwelt on the phenomena of polarization, on the methods of determining the optic axes in crystals, and on the measurement of angles of "extinction" as a means for determining the species in, for instance, the several triclinic felspars. The minute structure of vitreous rocks was next described, and the numerous changes set up in natural glasses, whereby they become opaque and stony.

In conclusion the Director gave explanations with regard to the names of several rocks, such as Diabase, Felstone, &c., and offered the subjoined Table of Classification of the chief Eruptive Rocks for consideration :—



ORDINARY MEETING.

APRIL 1st, 1881.

W. H. HUDLESTON, Esq., M.A., F.G.S., &c., President, in the chair.

The Donations to the Library were announced as usual, and the donors thanked.

The following were elected members of the Association :—

J. Knight, Esq., M.A., F.G.S.; Herbert Roper, Esq.; Reuben C. Green, Esq., and Capt. Underwood.

The following papers were read :—

1. "Notes on a Mandible of *Ischyodus Townsendii*, found at Upway, Dorsetshire, in the Portland Oolite." By E. T. Newton, Esq., F.G.S.

2. "A Geological Trip to Colorado in 1880." By S. R. Pattison, Esq., F.G.S.

Notes on the Mandible of an Ischyodus Townsendii, found at Upway, Dorsetshire, in the Portland Oolite.

By E. T. Newton, F.G.S.

During the excursion of the Geologists' Association to Dorchester and the neighbourhood, made in 1879, under the guidance of Messrs. Blake and Hudleston, Mr. W. H. Davis was fortunate enough to obtain the left mandibular ramus of a chimæroid fish from the Portland Oolite at Upway; the precise position being, as he tells me, about thirty feet below the "dirt bed." This specimen, which Mr. Davis has kindly placed in my hands for examination, is a small example of the gigantic *Ischyodus Townsendii* of Dr. Buckland, and it seemed to me that as the species is not of very frequent occurrence, a short account of the specimen might not be unacceptable to the Association.

The relative sizes of this ramus and Dr. Buckland's type will be gathered from the fact that, while the former measures five inches from the tip of the beak (fig. 1 *a*) to the post oral angle (*g*), the latter measures seven inches between the same points. The general form of the Upway mandible will be best understood from the figures. The symphysial margin (*a* to *f*) is slightly curved; the beak is prominent, and the oral margin immediately behind it is more deeply excavated than in the type. (*Vide* Agassiz Poiss. Fos., Vol. 3, pl. 40, fig. 20.)

The outer surface is strongly marked by longitudinal grooves, which run parallel with the symphysial margin, and it is divided into three areas by two wide depressions which run in the same direction as the grooves. Towards the oral margin there is a bony thickening upon which fine lines of growth may be seen, crossing at an angle the grooves just mentioned.

The symphysial surface (fig. 2., *a h f*) is narrow, and the upper margin has the ridge and groove constantly found in this genus. The inner surface (fig. 2, *a h g*) has its hinder part covered with the usual shiny lamina. There appear to be only two teeth, the large median one (*e*) and the beak tooth (*a*); but upon closer examination, a portion of the median tooth, towards the outer margin, is seen to be partly separated from the rest, and this may represent the small irregular tooth found in this position in the type, and other examples of *I. Townsendii*. The median tooth

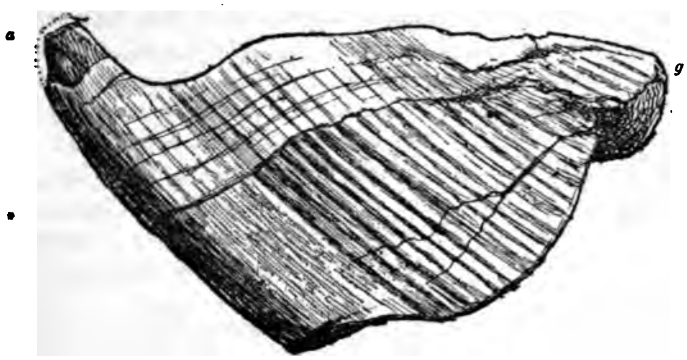


Fig. 1.

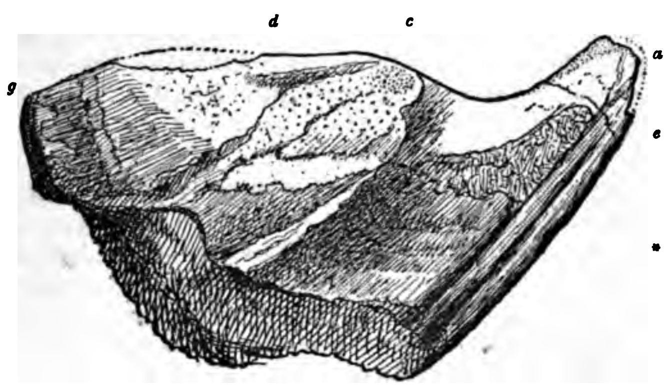


Fig. 2.

Ischyodus Townsendii, Buckland :—

Fig. 1. Left ramus of mandible, outer surface.

Fig. 2. Ditto ditto inner surface.

a. Point of beak with tooth.

c. Position of anterior outer tooth.

d. Position of posterior outer tooth when this is developed. The specimen is broken at this point, but there is no tooth.

e. Median tooth.

a to *f*. Lower symphysial margin, the asterisk (*) marks the edge of the bony thickening of the oral margin.

a to *h*. Upper symphysial margin.

a to *d*. Oral margin.

d to *g*. Post-oral margin.

g h f. Hinder margin.

itself is large, and occupies as nearly as possible the middle portion of the inner surface, extending through the thickness of jaw to within a short distance of the outer surface. There is no trace whatever of any posterior outer tooth, which is so commonly met with in other species. The beak tooth is not very distinct; but may be traced for nearly an inch from the point of the beak, the hinder part gradually thinning away. There is, perhaps, a very slight indication of this tooth becoming broken up into several parts, but there are no definite divisions such as are found in the larger specimens.

It was in the year 1835 that Dr. Buckland first described the species *I. Townsendii* before the Geological Society (Proceed. Vol. 2, p. 206), founding it upon the large left ramus of a lower jaw, and referring it to the recent genus *Chimæra*, as indeed, were all the chimæroid fossils then known. In 1843 Sir Philip de M. Grey-Egerton established the genus *Ischyodus* and included in it the species *I. Townsendii* (Proceed. Geol. Soc., Vol. 4, p. 156). About the same time M. Agassiz redescribed and figured the species (Poiss. Foss., vol. 3., p. 343).

Ischyodus Townsendii is by far the largest species of the genus at present known and, in common with the rest of the genus, has a narrow symphysial surface with the upper margin forming a rounded ridge (fig. 2, *a h*). The outer surface of the mandible has a very obvious bony thickening towards the oral margin (as in fig. 1). The beak is short and not produced as it is in *Edaphodon*.

The chief specific characters of *I. Townsendii* are the large size of the median tooth, the absence of the posterior outer-tooth, the small size of the anterior outer one, and the tendency which the last mentioned tooth, and that of the beak, have to become divided into separate portions.

If now the specimen from Upway, described above, be compared with reference to these characters, it will be found to possess all the peculiarities distinctive of *Ischyodus*, and there can be no question as to its being correctly referred to that genus. On the other hand, the specific characters do not agree so precisely. The large size of the median tooth and the absence of the posterior outer one are points in which they agree; but the absence of the anterior outer tooth would seem to militate against their belonging to the same species. However, as we have already seen, this tooth is irregular in form in *I. Townsendii*, and is always very close to

the outer corner of the median tooth; it may well be, therefore, that the portion of the median tooth in the Upway specimen, which seems to be partly separated from the rest, may be the representative of this anterior outer tooth, and would probably become more distinct as the creature increased in size. Again, the beak tooth in the Upway specimen does not show the same division into separate portions as it does in the larger specimens of *I. Townsendii*; but this also may be due to the specimen being part of a young individual. On the whole, this Upway fossil agrees much more closely with *I. Townsendii* than with any other species, and, in spite of the above-named differences, I do not feel any hesitation in referring it to that species.

Ischyodus Townsendii is only known as a Portland Oolite species. The type was obtained from Great Milton, near Oxford, and there is a second mandible in the British Museum from N. Wilts; in the collection of the late Sir Philip de M. Grey-Egerton, Bart., there is a premaxilla, and we have now to add the third mandible from Upway. Curiously enough the remains of this species have been found much more abundantly as derived-fossils in the peculiar Neocomian deposits at Potton and Upware. The only knowledge which we have of the form of the *maxilla* is derived from a rolled specimen obtained at Potton. (*Vide* Memoirs, Geol. Surv., Monograph 4, page 35.)

A Geological Trip in Colorado in 1880.

By S. R. Pattison, Esq., F.G.S.

The Geology of Colorado has been well known since the year 1867, when Mr. Hayden, U.S. Geologist, undertook the survey, and published in 1873 the first of the remarkable series of volumes which have made the structure of America so plain to us, and disclosed a startling array of facts concerning the newer world beyond the Missouri.

On going westward from Chicago, the traveller enters the flat corn and wheat lands which extend away to the north-west. All features are by degrees left behind save the boundless plain. On nearing the Missouri, we discern a broken line of low bluffs, amidst which the city of Council Bluffs tells by its name of the vain remonstrances of the Indians on being obliged to begin their con-

tinuous retreat towards the setting sun. Whilst changing from the Eastern line into the Union Pacific, we may note for a moment the features of the bluffs within sight. These are composed of yellow marl, and are the sides of a river valley excavated in what Sir Charles Lyell terms loess. This was deposited after the present surface was fixed; but there has been certainly one, and probably more than one, elevation since the deposition, for above Decatur, where the banks are formed of cretaceous sandstones, the Indians have made inscriptions on them. Mr. Hayden says:—"Many of these hieroglyphics are in positions totally inaccessible to the Indian at the present time. None of them now living know anything about them, and it is supposed that they must be very ancient, and that, since they were made, great changes must have been wrought in these bluffs by the waters of the Missouri. It seems strange that none of these hieroglyphical writings, which occur quite often on the chalk-rocks of the Niobrara group, higher up the Missouri, are known to any Indian now living. Marnel's Creek is called, in Dakota language, the creek where the dead have worked, on account of the markings on the rocks."

The broad valley of the Mississippi was a lake whose sediments now reach, in some places, a thickness of 150 feet. In these are found shells of existing fluviatile molluscs, bones of the Mastodon *(Elephas Americanus)* and its allies, with some remains of present mammalian forms. The bones are found chiefly in the lower part of the deposit, which also contains boulders from the distant Rocky Mountains, stretching in diminishing size and numbers eastward from the foot of the ranges for about a thousand miles.

Below the loess are beds of carboniferous limestones on the east, succeeded by tertiary clays towards the west.

From the Missouri the prairie country stretches uninterruptedly on every hand. The direct westward track by rail to the foot of the mountains is 650 miles, with a grade apparently level, but really rising imperceptibly until at Denver it has risen 5,197 feet. Throughout all this traverse the strata lie nearly horizontal until we near the foot of the mountains, when they are lifted to a high angle and tilted against the metamorphic and gneissic bosses of the great hills. On the prairie we get but few opportunities for geological observation. The surface soil is for the most part a distinct covering of good dark mould, with small angular

pebbles. On the river banks this appears to be often 30 feet in thickness, and is of fertility practically inexhaustible. Beneath this, and often inseparable from it, is a small loamy deposit of the loess referred to just now. In some places the lower, pebbly portion of this forms the surface. It is in this, the great Mastodon gravel, that a few, very few, traces of man have been found. The course of the rail brings us on to the line of the Platte river after about two days' travel. It is a constant, but very shallow stream, fringed with wood—a welcome sight—and with reeds and tall plants. Its average width is three-quarters of a mile, and its average depth only six inches! This reminds us of some of the thin freshwater beds of the old rocks, produced by the periodic overflow of shallow waters. As we now see occasional breaks, and discern several formations, it will be a convenient point for summarizing the sedimentary strata of the great tertiary central area of North America, which is *old* tertiary. All the upper beds show fresh-water molluscs, but change to brackish conditions with oysters of tertiary types, and with several alternations of marine beds in the descent towards the cretaceous series. In tertiary times this must have been a land of lakes and islands, and occasional marine occupation. As we examine the successive development of clays and sands, we soon learn that the three great divisions of the tertiary established by Sir Charles Lyell are equally convenient here as an artificial index.

The Eocene is here called the Lignitic group, the upper portion of which (Oligocene?) is distinguished by a large and beautiful flora, comprising fan-palms and tropical forms, and containing also remains of the hippopotamus and sabre-toothed tiger, and beds with river shells. The uppermost portion of this is a fresh-water stratum with bones of turtle; next above comes a full Miocene group, composed of limestones, sands and clays. The fauna is all extinct, including Machairodus, Rhinoceros, Cheiropterus, and the marvellous collection of mammals described by Professor Marsh and now at Yale College, with silicified wood and a large, fine flora.

Succeeding this upwards, on the Platte river, is a Pliocene deposit with bones of *Canis*, *Felis*, *Equus*, &c., scarcely distinguishable from modern species. Within this, and rising in very irregular masses, occurs the area of our chalk and greensand. The higher beds of the cretaceous series met with on the Missouri, and again near the Rockies, are Belemnite-sandstones, with bones of

Mosasaurians and numerous fossils. Under these are plastic clays, with *Nautilus Dekayii* and another form of Mosasaurian. A barren middle zone separates the fossiliferous beds. There are chalky beds, with oysters and fish scales; underneath these are strata containing *Inoceramus problematicus*, *Nautilus elegans*, *Scaphites Warreni* &c., in grey clays with thin coloured limestones, appearing to be on a level with our upper greensand. I saw numerous fossils at Manitou from these beds.

Lowest of all is the Dakota group, with its lignites and remarkable assemblage of plants, well known to us through the labours of Hayden and Lesquereux. Thus, whilst the upper cretaceous is disturbed and mixed, the lower is a tranquil sediment.

The Dakota group in its marine beds is known by the forms of Inoceramus and its associates; but the sandstones contain saurian remains and a flora remarkable for its richness in dicotyledonous trees. The latter record here their first appearance, in force, on the earth by a sudden burst so far as we know at present. The leaves and fruit have been described by Lesquereux in the publications of the States Survey, and denote a sub-tropical vegetation, differing wholly of course from those now growing, though remarkably similar. They comprise cinnamon, laurel, sassafras, magnolia, and other well-marked forms. These rocks have a very wide extension along the base and amidst the inlets of the Rocky Mountains.

Inside these again is a grand exposure of triassic beds, reduced to discontinuous fragments by inconceivably powerful denudation. They form a broken necklace as of dark red coral around the foot hills, and constitute the monument series, as it is called. Monument Park displays huge lumps and needles of these variegated red rocks, comprising coarse pudding-stone or conglomerate, and every grade of sandstone. This is occasionally capped with basalt, and is thus protected, exactly as is the chalk in Antrim. These shapeless lumps are favourite objects with photographic artists. They constitute the peculiar scenery of the "garden of the gods;" there they are flanked on the one side by cretaceous layers, and on the other by some coal-measure grits and limestone, but all so tilted and naked as to compose very singular landscapes. Mr. Hayden, speaking of the erosion of the Trias, says :—

"Whatever may have been the agents which in times past have

wrought out all these remarkable forms, it is plain that they have acted in former times with far more intensity than at present."

In this part of Colorado the Trias is the most extensive of all the sedimentary unmetamorphosed formations; but it is so remarkably denuded as to display a surface like the monuments of Carnac in Brittany.

The uplift of the mass of the Rockies must have preceded the Trias, for the great conglomerates of the latter were formed when the metamorphic and granitic rocks of the main chain constituted the coast line, and these pebbles were the shingle beaches.

Resuming our route—which we have anticipated by some hundreds of miles—we observe between Cheyenne and Denver much surface-blown sand. There are sand-fences put up to defend the line of railway from invasion by drifts at particular points. Here, too, we pass desert places where the soil is so alkaline that nothing but the sorriest grasses and scrub can manage to live.

I omit all mention of the great mining centre; man and *his* work are too recent here to be interesting. It is the capital of a State which boasts of a number of mountain peaks above 14,000 feet high, 200 between that and 13,000, and an innumerable forest of lower heights and rock masses with cañons, having nearly perpendicular walls of a thousand feet and upwards, and in some cases cañon within cañon. Ever since the discovery of a silver lode in 1869, it has been, as it is now, the scene of active mining enterprises.

On leaving Denver again for the north-west, we run along the front of the mountains and reach the foot-hills at Golden. At Golden the sedimentary rocks have been removed, leaving the great hard red rock as tumbled foot-hills at the base of the grey quartzose gneiss and granite. Outside the former are fragments of cretaceous strata; the gneiss abounds in quartz veins, from the contents of which the place derived its name. Golden is outwardly distinguished by its tall chimney-stalks—tokens of considerable manufacturing industry.

In broken lines all down the eastern front of the Rockies, coal occurs, and is mined and used for all purposes. It is rather light, and appears to occur both in the tertiary and in the cretaceous series, but principally in the former. It is worked a good deal,

being opened as fast as the railway system extends. The production and sale has run rapidly up to 300,000 tons per annum. I saw much of it on the line; it is of varying quality, but most of it is a good bituminous coal.

The usual results from productive coal measures are sure to follow; already there are in the southern borders of Colorado iron furnaces, a Bessemer steel plant, and a rail factory.

We are now near enough to the mountains to see their structure. Granite constitutes the central mass, bald at the summits, broken and grey, but oxidised into red in vast ranges. Piled up against this, and often covering it, are old gneissic and metamorphic rocks of varied hue and form, and still more highly coloured and broken are the secondary and tertiary rocks of the foot-hills, varied by long lines of forest and grassy terraces overlooking the plain, and by the dry lake-basins which constantly occur among the mountains, and constitute a leading feature of the scenery.

The chain is crossed occasionally by transverse ranges, and broken through by the grand fissures through which the rivers run. Here and there are bands and bursts of trappean rock. The width of this enormous mountain mass varies from 300 to 1,000 miles, and in length it appears to stretch from the Arctic circle to the tropics.

In approaching it here, we go right into a scoop in the hills surrounded by terraced slopes and diversified by jutting rocks of sandstone, and some peaks of greenstone. Occupying this is the town of Boulder, at the mouth of the famous cañon of that name. From this place, the road up the cañon having been washed away, we mounted a buck-board, drawn by a pair of fleet ponies, and ably charioteered by Mr. Delavan Peek, of Ni-Wot, to whom an introduction proved to be a free ticket with endless coupons. We had to traverse the boulder-strewed plain, and make for the parallel of Jim Creek. We then ascended that remarkable gorge. Immense masses of metamorphosed sandstone belonging to the foot-hills first blocked the way, then the usual succession of red schistose strata, and the grey gneiss, and lastly granite. Half way up we came to a mica mine. The mineral occurs in a quartz rock. It is split and trimmed like Welsh slate. It is a very remarkable article and much used in powder for lubricating and packing machinery. We had full opportunity of examining the development of *placer* mining. The deep deposit of irregular

gravels and sands in the gorge, cut through by the fierce stream, and cut through over and over again by the works of the gold miners, displayed all the features of the original fissure, the wearing down, deposit of debris, and successive disturbances by men wielding hydraulic power furnished by the turbulent stream. This and a few similar passages in the course of the following days gave me some insight into a subject deeply interesting both to the student of the antiquity of man and of the work of the miner.

The cañons here owe a portion of their picturesque character to the varying composition of the rocks through which they are broken and worn. They approach the sublime in the upper reaches where they are frequently bounded by lofty pinnacles of grey granite rock, possessing the characteristic open joints and frequently springing as it were from the jagged reddened rocks of the metamorphic series. The frequent waterfalls and basins where gravel has lodged, and the constant exhibition of the work of air, water and ice induce some generalisations.

Atmospheric agencies and probably occasional earth-movements have degraded mineral veins, and decomposing portions as well as huge masses. These have been carried down the cañons and galleries, grinding as they go, and spreading out finer and finer detritus in the descent. Where the parent vein contained gold or tin, specific gravity has caused it to be sorted and deposited at the point of least motion, and these are the rich "finds" of the gold miner, and Cornish tin streamer alike. Underneath the drift the rocks are frequently said to be grooved as by glaciers, whilst the local accumulations and varying lines of bedding, show that the valleys were frequently gorged with ice and scoured by floods.

But amidst this apparent confusion there appears to be evidence of two very distinct and distant periods of action, one apparently coeval with the glaciation of the rocks, or nearly so, the other subsequent, and clearly belonging to the time of present levels, and configuration and height of the valleys.

The upper reaches of the forest brings to view a general feature which was novel to me, namely, a broad belt of at least three miles wide, of slaughtered trees, lying prostrate as whitening skeletons in every stage of decay. The timber line is here 11,000 to 12,300 feet high. The pines, growing on the last 3,000 feet, yield to extremes of wind, and of course the weakest, *i.e.*, the highest, are the feeblest. Thus the number of the skeletons

increases with the height and the mountains are all closely girdled by them, the living trees predominate downwards until the ghastly whiteness which prevails at the top is succeeded by the normal green of the lower forest. The snow lies in patches about and above 14,000 feet. The flora up to this is abundant and beautiful.

On we went through the solemn forests up to Ni-Wot, where in a comfortable log-house, at an elevation of about 10,000 feet, we stayed some days in perfect mountain solitude.

We were near the great Columbia vein, in fact on it, and I went down into it at Ni-Wot, and at a mine called Nelson on a parallel lode. The lodes were true fissures, nearly vertical, one wall was apparently a porphyritic trap, the other coarse metamorphosed schist. The lode stuff was quartzose and felspathic rock of loose texture, containing coatings of pyrites in which is found the gold.

The pay vein forms only a small and irregular portion of the lode, varying from nil to 2 feet in a crevice from 12 to 20 feet wide. The copper and silver are secured as well as the gold, but the ore is very refractory and furnishes but a small quota at present of the five million pounds sterling, now the yearly produce of the Colorado mines.

A traverse into the glacier lake district of the Arapahoes, an ascent of Bald mountain, afforded an opportunity of seeing the upper scenery of the Rockies, which is well worthy of its reputation. I examined several deposits of the substitutes for bogs which is called "duff," and consists of the fallen leaves of the fir accumulated in a peaty mass by the rains until it becomes of a spongy texture and holds water like a moss, and like it swells and retains the falling or surface waters, and holds them as a magazine for continuous supply all the year through. I saw only a few spots of true moss, but vast extents of varying thickness of this duff. The occurrence of duff is another instance of the all-important function fulfilled by forests in regard to climate and water supply, and the formation of coal past and future.

I now went through some of the famous gold mining districts of Ward County. The conspicuous feature to a geologist is the coarse gneissic and granitic rock, with bosses as though denuded, seamed with quartz veins. Descending, unwillingly, again to Denver, I went southwards by the Rio Grande Railway, through

the remarkable triassic rock exposures of "monument" to the new city of Colorado Springs.

Colorado Springs is favourably placed for geologizing as the foot hills are much broken and tossed, and the huge mass of Pike'sPeak displays the fundamental rocks in a very striking manner. There are two stores of mineral and natural curiosities in the young city, one of which is dignified with the title of Museum on the strength of some unfortunate bears, wolves, panthers, and lynxes kept in durance vile in a back-yard. The display here of the large crystals for which the granite veins are renowned is worth attention, and here I obtained the plant and insect remains which I lay before the Society. They came from Florissant, a place about 30 miles up the Ute pass which, unfortunately, I could not find time to visit. Though small and fragmentary they are well preserved, and to an unskilled observer, they look like an oligocene group. Thence I was glad to get to the upper summer resort of this district—Manitou.

The original cause of the selection of Manitou was the occurrence of soda-springs in the line of the little stream, which is named from this Fontaine-que-bouille, and was much regarded by the Ute Indians as an outburst or speech of the Great Spirit (Manitou). The springs issue with considerable force and heat just at the junction of the sedimentary and metamorphic rocks. The largest throws up five or six gallons per minute. The proportion of iron varies in the several springs, which are resorted to for curative purposes. The Ute Indians regarded the principal spring with religious reverence, and some time after the settlers had commenced surveying, the Indians came down one day in single file on horseback, rode round the spring, casting into it an offering and riding away. After their visit it is said by the Government surveyors that over a bushel of the offerings in gold ear-rings and ornaments, was taken out of the bubbling spring. The spray leaves a solid incrustation around some of the outlets.

The village is the converging point of several beautiful cañons The one on the right is called William's Cañon. The central one is the Ute Pass, the one on the left is the Pike's Peak Cañon.

In William's Cañon the Jurassic rocks occur with coal and silicified wood. The limestone caves in the vast precipices of frowning reddened rock, greatly increase the picturesqueness of the scenery, which has indeed all the features which an artist loves, and owing to the broken character and vertical bedding of the rocks,

the geologist is furnished with constant surprises. The Silurian strata here rest unconformably on an older schistose rock, which may be a member of the Cambrian. There are bars of igneous rocks broken through and worn down at the foot of the huge walls of gneiss and metamorphosed old rocks, rendering the combination, aided by luxuriant vegetation, inexpressibly beautiful.

My farewell exploit was the easy ascent of Pike's Peak up the cañon which rises direct from the end of the village, through the red rocks, and the gneiss, by the cataract of boulders fallen from the pinnacles above, or by veins containing huge crystals of smoky quartz, and of orthoclase, and other minerals, up to a kind of clinker granite at the bare summit, here sprinkled with snow. The height is 14,137 feet, and I experienced, for a few moments only, some pain in breathing. I need not enlarge on the view in the clear air—the mountains of San Juan, in Mexico, 174 miles away in the south—the long northern range into Montana—the prairie extending infinitely, as it appeared, on the east, with the Platte river in folds glistening on its surface—on the west the view of the sea of mountains and parks, old lake beds, rocks, woods, and gorges, over into Estes Park—was amazingly grand and beautiful. But I must spare you any attempt at describing the indescribable. The ascent gave an opportunity of considering the cañons with a view of ascertaining their origin.

My decided impression is that the cañons were original fissures, broken and jagged, either by upheaval or depression, and eroded through countless ages by atmospheric agencies in the higher portions, and by the added action of streams in the lower reaches. The course and work of the last named may be traced in the dry lakes and lake barriers, which now as grassy hollows dot and beautify the scenery.

The marks of glaciation which I noted are about 1,500 feet up, *i.e.*, about 8,000 feet above sea-level. The drifts appeared to me to be all such as were furnished by the rocks immediately above and around.

Mr. Hayden, in his first report, remarks that the traces of ice action on the east show that the mountains were once much higher, and that the present high gravel ridges and buttes are the relics of that time. That afterwards, and by long continuance of glacial conditions, immense quantities of drift were deposited, and the slowly decreasing forces produced diminished results.

One of the interesting of the many questions which rise out of the facts displayed in this district is that of the age of the gravels, which is closely connected with glacial phenomena on the one hand, and with the human period on the other.

It was my impression, from such examination as I could give in the Boulder and Pike's Peak districts, that the gravels may be divided into two series, first those which were the result of glacial action, or action in glacial times; secondly, the results of subsequent subaërial or physical forces. In Cornwall the tin pebbles are only found in accumulations of the later date, probably because there are no glacial gravels; but in America, where there are the debris of granitic and gneissic and metamorphic rocks spread out by the agency of ice and snow, gold is found in the gravels of both series. In the first it has found its primary bed, and then, on this having been re-made by subsequent action, it is re-sorted with additional materials. Lastly the bed has been again disturbed by man in his search for the nuggets of the precious metal during nearly a thousand years. Of course the gold, being the heaviest portion of the load carried forward by the waters, would fall closest to the parent rock, and would be lodged in the pockets and cheeks of the gorge, especially at the upper side of the contractions of the latter, or where the turbulent current was checked by an angle in the bed. Accordingly the placer miners in one country and the tin streamers in the other both study the rocky sides of the hollow in which they work. In the Rocky Mountains the slopes are so steep and the rushes of water so powerful, the effects of present causes so intense and extensive, that it becomes extremely difficult and often impossible to separate (using antiquated language) the diluvial from the alluvial.

Another feature which must strike every traveller is the extreme rapidity with which all effects are obliterated and become undistinguishable from phenomena prior in time. This of course occurs in all mountain districts, but on account of the bald summits and frequent coarse veins, and the dirt bed of a timber line 12,000 feet high, it is eminently the case here. The flood-changes which are rare phenomena in the upland valleys of our own country, are constant occurrences here. The observer is soon taught that it is impossible to tell whether he is in glacial gravels or in accumulations under ten years old, so rapid is the process by which nature reasserts her tranquil beauty. Hence the unreliableness of the attempt to introduce time or dates into our calculations, in regard

to any extraneous objects such as worked stones or pottery found in the auriferous drift. When worked flints are numerous, and lie just like other pebbles, as in the gravels of the Somme Valley and England, we know that they are original portions of the bed, and therefore as old as the latter. But when they are isolated finds, and especially accompanied by things believed to have been of various dates, and all more or less supposably connected with gold seeking, we cannot be sure that they are contemporaneous with the first deposit of the gravel; nay, we reasonably infer that they are not. Hence I entirely distrust the alleged proof of antiquity claimed for the articles which have been reported from the drifts. Like the celebrated bits of bread-and-cheese brought up in the 500 feet sinking for coal, they betray their own recentness. I mean that they belong to the mammalian gravels, and are not, at most, older than our implement-bearing gravels.

We are thus, as in Europe, brought back to the conclusion that at a period far, very far, back through all the ages it may be of the Post Pliocene, or at some epoch in this long progression—sometimes, so far as our present evidence goes, when the glacier conditions were yielding to more moderate temperature, and the land was still occasionally subjected to elevations and subsidences—man appeared in both regions, as a hunter on the plains and a dweller in the dens of the earth.

I had made these notes before I met with Mr. Whitney's recent publication on the researches of himself and his staff amongst the auriferous gravels of the western slope of the great American chain. Of course it would be irrational to dispute the facts collected by so able and indefatigable an observer as this great geologist, but I must venture to say that his conclusions are not warranted, so far as I could see, by the appearances on the eastern side of the same chain. Let me recapitulate Mr. Whitney's deduction.

First, that there was an accumulation of water-worn *debris* along the sides of the rivers flowing down from the hills. Secondly, interstratified with these were heavy deposits of volcanic materials. Thirdly, there was a continuance of igneous agency. That this was going on during most of the tertiary period, and is coeval with the latter. That whilst the Eocene and other tertiaries were being formed elsewhere, the auriferous gravels were being deposited. Fourth, that the cañons were excavated at the same period,

and the causes have gone on to produce the same effects, but with diminishing action. Fifth, that this gravel period is older than the glacial, and that "ice had nothing to do with any part of the erosion of the glacial period." That not until all the gravel had been piled up was the higher portion of the Sierras occupied by glaciers. That all the cañons had been cut out, and the whole topography, down to its minutest details, was just what it is now before ice had any existence in these parts. Sixth, that the terms Eocene, Miocene, and Pliocene, have no application here, where there never was any tertiary. Mr. Goodyear supports this by his statements founded on extensive surveys in the northern area of the great Pacific slope. Both attribute much to the slow ordinary action of present causes; but both adduce interruptions by paroxysmal action. I must, in few words, say why I dissent from these conclusions. In approaching the Rocky Mountains from the east I find sheets of mammalian gravel as well as sundry deposits of brick-earth everywhere forming the soil, and cropping up here and there from underneath these is a great lignitic tertiary formation. The drift may be traced up to the foot of the hills, and up their lower slopes, distinctly covering the tertiary, not as an integral portion of the latter, but as a subsequent mantle extending over all the tertiaries as well as the secondary rocks along the whole line. Now it is in this drifted covering that the remains of mastodon, and alleged traces of man occur, in fact it is the home of the great mammalian fauna. Is it not inconceivable that this should happen on one side of the mountain chain, whilst the other should distinctly contradict it?

Then as to the effects of ice. On the eastern side I saw the lake basins, the moraines, the scratched boulders, the peculiar arrangement of boulders and gravel which Agassiz long ago taught us to connect with glaciation. Is it possible to assign one epoch to these phenomena on one side of the chain, and a totally different epoch on the other?

If the pre-existence of man to the glacial epoch is supposed to be proved by the contemporaneity of the gravel in which his remains have been found with the tertiary period on the western slopes, I demur entirely to the conclusion on stratigraphical grounds.

The published observations of Mr. G. M. Dawson, the son of Dr. Dawson, of Montreal, and Government Geological Surveyor in British Columbia, published in the Quarterly Journal of our

Geological Society, "On the Superficial Geology of British Columbia and adjacent regions," also appears to be in direct opposition to the views of the American geologist, for he says that the boulder work of the glacial period is distinctly posterior to the tertiary, and that glacial action and its results have clearly affected the prior formation, including the pliocene. He says:—"Boulder-clay is spread over the entire district; terraces are cut in the rearranged material of this, bordering the river-valleys, and at greater elevations expanding over the higher parts of the plateau and mountains. Some of the wide trough-like valleys of the plateau contain a silty material which the author regards as a glacial mud. North of the 54th parallel and west of the Rocky Mountains similar evidence of glaciation is obtained. The fjords of British Columbia are extremely glaciated, the marks being generally in conformity with the local features." He "considers that the most probable explanation of the phenomena of the whole region is to suppose the former existence of a great glacier mass resembling the inland ice of Greenland, and that the Glacial period was closed by a general submergence, during which the drifts were deposited and, at its close, the terraces cut."*

In a letter published in *Nature*, January 27th, 1881, Mr. G. M. Dawson further controverted the general conclusions of Professor Whitney, and shows that whilst only a small portion of the highest range of the mountain has been covered with glaciers, yet there has been, in this as on the other side of the range, a decided northern drift period, distinct from and posterior to the tertiary. I, therefore, conclude that the Rocky Mountains, on both sides, display the same succession of phenomena as has long been proved to have occurred elsewhere, and that the superficial drifts are recent, that is to say post-tertiary.

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* Abstract of Proceedings, March 9th, 1881.

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY), SOUTH KENSINGTON.

SATURDAY, APRIL 9TH, 1881.

Director :—DR. HENRY WOODWARD, F.R.S., F.G.S., KEEPER OF THE DEPARTMENT OF GEOLOGY.

A large party of the members, including the President and most of the officers of the Association, were met by the Director in the central hall, known as the Index Museum. Previous to conducting the party through the Geological galleries, the Director distributed amongst the members copies of a "Guide to the Exhibition Galleries in the Department of Geology and Palæontology."

This very useful pamphlet, to be issued to the public at the price of one penny, had just been completed by the Director in time for the visit of the Association, and shortly before the admission of the general public, which was to take place on the Easter Monday following.

The Director, after leading the party through the South East gallery, which is devoted to the exhibition of the Fossil Mammalia, into the Pavilion, gave a short but succinct account of the arrangements, in part completed, for the accommodation of the vast collections committed to his charge.

The specimens in the Geological galleries are arranged zoologically, and under each is placed its name, geological position, and locality. Only two of the galleries being at present in a condition for opening, and these but partially arranged, the entire collection is not yet visible ; the fossil Mammalia, Birds, Reptiles and Amphibia were all that could at present be shown. The party then passed through the narrow Reptilian gallery, devoted to the Ichthyosaurs, Plesiosaurs and Dinosaurs.

Ascending to the first floor they were received by Mr. Fletcher the keeper of the Mineralogical collection, which was in a very forward state, though the Pavilion at the end of the gallery was somewhat disturbed by the fixing of a huge meteorite. The light in this gallery is said to be satisfactory, and the pillars are less in the way than they seem to be in the corresponding corridor on the ground floor.

Previous to leaving, the members of the party, which had

gradually become dispersed throughout portions of the vast building, reassembled in the Index Museum to offer, through the President, their thanks to the Director for the facilities afforded in the inspection of the New Museum, where they had spent an afternoon in a manner both agreeable and instructive.

EXCURSION TO SALISBURY, STONEHENGE, AND VALE OF WARDOUR.

EASTER MONDAY AND TUESDAY, APRIL 18TH AND 19TH.

Directors—THE PRESIDENT, JOHN S. PHENÉ, Esq., M.D., F.S.A., F.G.S., and H. P. BLACKMORE, Esq., M.D.

(*Report by the* PRESIDENT.)

The party from London, conducted by the Secretary, Dr. Foulerton, arrived at Salisbury shortly after 11 a.m., and on securing quarters at the several hotels, found their way in detachments to the Blackmore Museum. A section of the members took this opportunity of visiting the Cathedral, which, as a piece of masonry, built of the stone of Chilmark and Tisbury, is in every way worthy the attention of geologists, to say nothing of its splendid architectural attractions. The carving on the west front has recently been renewed with stone said to come from the uppermost Portland beds of Chilmark. The rest of the building is for the most part constructed of the lower building stone, and its very good state of preservation, considering the date of its construction, bears ample testimony to the excellent quality of the stone. The columns in the interior are of unpolished Purbeck marble, with polished shafts of the same; the latter are, in some cases, bent by pressure, and have required considerable repairs. The spire is said to be slightly deflected from the perpendicular, to the extent of about one foot measured on the floor, and has been in this condition for a very long period.

Meantime Dr. Blackmore had received a portion of the party, and had already commenced the demonstration of the mammalian remains from the low-level gravels of Fisherton and Bemerton which are preserved in the Museum. This Museum was founded in 1864, by the late Mr. William Blackmore, of Liverpool and London. It consists of one large room, 70ft. long by 35ft. wide with an entrance-porch on the north, and a committee-room and

other offices in the rear. The large room is covered with a hammer-beam open timber roof, which, with the aid of polychromy, imparts an agreeable appearance to the Museum, the effect being greatly heightened by the warm tone of the encaustic tile floor. Simple, convenient, and by no means destitute of beauty, this warm and well-lighted room, kept so scrupulously clean, is the very type of what a museum building should be, where the primary object of exhibiting a collection is not sacrificed to architectural fancies, too often hideous in their realization.

The general arrangement is as follows :—Group I. Remains of animals found associated with man. Group II. Implements of stone. Group III. Implements of bronze. Group IV. Implements, &c., of modern savages, serving to throw light upon the use of similar objects belonging to prehistoric times.

The remains of mammalia are mostly from the lower gravels underlying the brickfields at Fisherton, about a mile to the west of Salisbury. These consist of bones or teeth of *Hyæna, Felis, Canis lupus, Spermophilus, Lemmus, Elephas primigenius, Rhinocerus tichorinus, Cervus tarandus, Bison priscus, Bos primigenius Ovibos moscatus*, &c.

In the brickearths of the same locality are found such fresh-water shells as *Ancylus fluviatilis, Lymnæa palustris, Planorbis carinatus, Bithynia tentaculata, Pisidium fontinale*, &c.; and such land shells, as *Succinea putris, Pupa muscorum*, and several species of *Helix*.

The collection of flint implements is most choice and extensive, no pains or expense has been spared to make it as complete as possible. The chief interest here may be said to centre in the collection of the Palæolithic period, and especially of the Drift series, from the neighbourhood of Salisbury, both on Milford Hill, and on the hill which divides the Avon and Wiley Valleys above Bemerton. But besides these are implements of the Cave series from other districts. The implements of the Neolithic Period are also abundantly shown, and there are collections illustrative of the lake dwellings of Switzerland, &c., and of the shell-mounds of Denmark, besides a most wonderful series both from North and South America.*

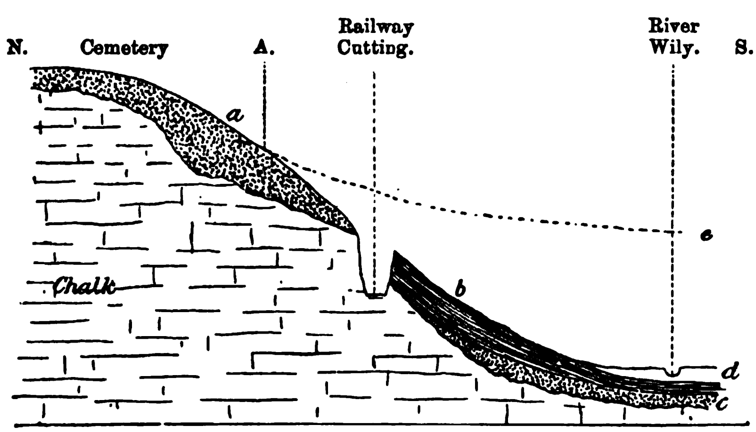
* The Salisbury and South Wilts, and Blackmore Museums are in St. Ann Street, Salisbury. The current expenses are defrayed by annual contributions. A sum of £2 15s. was presented in the name of the President and Members of the Geologists' Association, to the Treasurer, and duly acknowledged by him and Dr. Blackmore.

Amongst the curiosities is a collection of forgeries, together with an excellent photograph of that arch-forger, Flint Jack, who was perhaps even better known at Salisbury than in his native Yorkshire.

After a most able and exhaustive demonstration of these treasures, by the Director, the party adjourned to Milford Hill, about one, mile N.N.E., where excavations for the foundations of houses were disclosing sections of the high-level flint-bearing gravels. These consist of a brown clayey flint gravel, in which, for the most part, the implements are found, resting sometimes on a light-coloured and more sandy deposit, sometimes directly on the chalk itself. Several implements have been taken quite recently out of these beds.

The party now adjourned for lunch, and re-assembled at 2.30 p.m., when it was found impossible to carry out the entire programme, involving a visit to the deposits at Fisherton and Bemerton. As this section is of considerable interest and importance in explaining the nature of the finds previously mentioned, it is given below :—

SECTION AT FISHERTON.



Length of Section, about 250 yards.

a. High level quaternary gravel, containing palæolithic flint implements, but no organic remains.
b. Brick earth, containing land shells with few mammalian remains. Two or three flint implements.
c. Low level quaternary gravel, which has yielded the principal part of the mammalian remains, and a very few flint implements.
d. Alluvium.
e. Contour of ancient valley, 80ft. at A.

A tolerably punctual start was made for Stonehenge, distant nine miles N.N.W., and the first halt was at Old Sarum, a commanding point on the east side of the Avon, about two miles north of the present city. The following notes, prepared by Dr. Phené, were read out by the President to the party, when inside the mound:—

"Old Sarum was originally a British fortress, and was taken by the Saxon Kenric in 552 (skeletons recently disinterred on Hilford Hill are evidences of some of the fighting). Alfred the Great strengthened it. In 960 Edgar held a council of the nation to oppose the Danes. In the reign of Ethelred II., Sweyn took it. William the Conqueror founded the see, which was formerly that of Sherborne and Castleton, and held here his grandest council, as did William II. in 1096, and Henry I. in 1116. It was deserted by Henry III., as being deficient in water, and the see was removed to New Sarum (Salisbury) in 1219. Some houses remained in the reign of Henry VIII. It is said that here was a palace of the British and Saxon Kings, and of the Roman Emperors. The donjon mound is now the principal object. The old city appears to have been built entirely on the artificial British hill."

Once more the party betook themselves to the dusty road, which traverses the plateau between the valleys of the Avon and the Bourne, and presently arrived at Amesbury, whence the direction became due west. The Avon was crossed, and the remarkable earthwork known as Vespasian's Camp, sighted. Shortly after this the road emerges upon the treeless and lonely plain, where the mystic ring of Stonehenge seems yet to invite the archæologist to explain its origin. The shadows of the megaliths were already lengthening on the turf, though their solemnity was profaned by the flags and performances of Easter holiday makers, when the Members of the Association, over fifty strong, advanced in irregular column to greet the Director (Dr. Phené), who had approached with a party of friends from the direction of Devizes. The east wind whistled fiercely between the pillars, but, at length, a convenient spot was found to leeward, where the Director read his promised address, "On the origin of Stonehenge, the various periods of its construction, and its connection with Roman works."

The explanation advocated by Dr. Phené may be regarded, to a certain extent, as the Phenician theory. He considers the inner circle of stones as having been connected with the development of the tin trade in Britain. Hence, also, it is quite possible that these stones may have been brought from abroad. The larger

Sarsens were erected subsequently, as a sort of guard of honour to the smaller ring. The Director afterwards proceeded to point out certain peculiarities in the stones and their arrangement, favourable to his hypothesis.

The petrology of the inner circle has of late attracted much attention. Could these silent witnesses of an unrecorded past by any means be made to speak, how many theories would be consigned to oblivion! Yet they are not altogether dumb; if they cannot say whence they came, when properly interrogated they can tell us of what they are made. Professor Maskelyne, M.P., has recently published, in the "Journal of the Wiltshire Archæological and Natural History Society," an interesting article on this subject. An abstract of his results was communicated to the Members by the President previous to their departure.

There are *four* kinds of stones. The outer ring is composed of huge *Sarsens*—a compact quartzose rock, derived from the Tertiary Sands. These are, in fact, siliceous doggers or concretionary slabs of enormous size, which have hardened *in situ*, and have resisted the atmospheric agencies of destruction. Several fragments were picked up of this material, which seemed to bear the marks of roots or something of the sort. It is by no means improbable, therefore, that the decomposition of vegetable matter, and consequent formation of *humus*, and the various organic acids which arise from its gradual alteration into carbonic acid, may have had something to do with the concretionary action. The influence of these organic acids on silica has been the subject of interesting investigations in America.

The *second* variety of stone has only one representative, viz., the "altar stone." This is described as a grey sandstone, composed of quartz sand, silvery mica, and some dark grains. It is, in fact, a micaceous grit, and might possibly have been brought from the Old Red Sandstone of the Mendips near Frome. It much resembles the stone beneath the Coronation Chair known as the Scone stone.

The *third* variety, which comprises the bulk of the inner circle, includes 29 of the smaller stones. To these the term greenstone and even "syenite," has been applied; the latter name because augite was mistaken for hornblende. Prof. Maskelyne describes these, generally, as consisting of a white or greenish-white felspar, with broad crystals of brown and sometimes greenish augite. The felspar is probably labradorite; this is clouded and suffused with

chlorite. The rock may fairly be called a Diabase, though its mode of occurrence points to the possibility of the chlorite being contemporaneous. The augite is less decomposed. Magnetite and quartz are also present. The ground mass is sparse, but contains fine crystalline grains, some of which may possibly belong to a different felspar. As a specimen of their chemical composition, No. 4 afforded—

Silica	51·7
Alumina	12·1
Iron Oxides	15·3
Lime	10·0
Magnesia	4·08
Potash	1·02
Soda	2·80
Water (? Carb. Acid)	2·60
	99·6

The augite occurs porphyritically throughout, but in this specimen is more compact than in some, and the felspar in better order. The chlorite sometimes occurs in distinct triangular plates; and quartz crystals are also present, giving evidence of secondary action due to the crystallization of progressively dissociated silica.

The *fourth* variety has only four representatives. No. 9 is a siliceous schist, Nos. 11, 17 and 19 are hornstones, with specks of felspar and pyrites. These may be described as a variety of sedimentary and somewhat metamorphosed rock. The stones are harder than quartz, and have a sp. g. of 2·7 to 2·8. The general aspect is that of a triturated igneous rock, the materials of which have been redistributed by aqueous action; the fundamental character is that of a fine-grained mixture of quartz, felspar, and a grey chloritic mineral. They have a remarkable structure somewhat schistose. This arises from the quantity of chlorite, which is endogenous, whilst the other crystalline particles are clastic, and therefore exogenous.

In No. 17 there is magnetic pyrites, whose decomposition stains the rock. No. 19 afforded—

Silica	77·4
Alumina	13·5
Iron Oxide	3·5
Lime	1·8
Magnesia	1·3
Potash	0·60
Soda	0·73
Water and loss	1·30
	100·13

The Professor observes, with regard to the so-termed fluxional character, that it is by no means an uncommon feature in this class of sedimentary rock, built up out of the materials of the old igneous rocks, where the ground-mass may be observed in wavy lines round the uncrushed fragments and crystals. Similar rocks occur in the Cambro-Silurians of Wales and Cumberland, especially some described as volcanic ash, though none of these are volcanic ash in the usual sense of that term.

Meanwhile the ardour of some of the Members was beginning to cool under the influences of the piercing wind, and, as Dr. Phené had already disappeared, a general move was made to the carriages The route to Salisbury through the Avon valley was selected by the drivers. Besides being rather picturesque for a chalk district, it had the merit of having much more shelter than the bleak and open plain.

Tuesday.—A leaden sky and a cold wind were the precursors of a somewhat bitter day. No ladies appeared. About 9 a.m. Mr. Gordon called to collect a party for the Cathedral, and incidentally announced the death of the Earl of Beaconsfield, which had occurred a few hours previously.

About 10 a.m. rail was taken for Tisbury, 13 miles distant W. Shortly after moving out of the station, the train passes through the cutting shown in the Fisherton Section (see page 136), and thence proceeds up the Wiley valley to Wilton. Here the Wiley is joined by the Nadder coming from the west, and the line follows the valley of the latter, and may be said to fairly enter the Vale of Wardour near Barford, where the Upper Greensand is seen dipping to the eastward below the chalk at a considerable angle. The station at Dinton is built on the attenuated representative of the Neocomian beds, which are rapidly dying out to the westward; and beyond this, for some distance, the more important cuttings are in the Purbeck beds. There is no cutting which gives a good section of the Portland beds, though the line must run through the entire series down to the Kimmeridge Clay, over which the Nadder flows at Tisbury station. Here the party left the train.

Before starting, the President, who, on this occasion, acted as Director, distributed amongst the Members a number of pieces of Portlandian Coral (*Isastræa oblonga*), which is known in this district as "star-flint," being always found in a silicified condition. The specimens occur in the lower building stone series (No. 4 of

the Chilmark Section), and are found, not exactly *in situ*, but in a distegrated deposit formed by the surface weathering of this series on the high ground to the N.W. of Tisbury. Curiously enough it has never been detected in the equivalent of this series to the eastward.

Avoiding the town of Tisbury, the party made at once for Place House, situated at the junction of a trouty looking stream, from Fonthill, with the Nadder. By the kind permission of Mr. Brasher, who is Mr. Morrison's tenant, the party were permitted to inspect the curious old Barn and other buildings, which at one time belonged to the Wardour estate, and were erected by the people of Shaftesbury Abbey. Mr. James Parker acted as *cicerone* on this occasion.

Climbing up the steep hill above Place House, the party passed an old quarry in the Portlands, where the stone now extracted elsewhere is cut up by saws. They thence gained the high ground of Ladydown, which unfortunately was too exposed to be an agreeable resting-place. The view from here is extremely fine, and the stratigraphical features of the Vale of Wardour impress themselves strongly on all who take an interest in physiography. The Director explained the topography of the district, and the geological relations of the beds which compose it, dwelling especially on the subject of the anticlinal, and its relation to similar physical features elsewhere. This done, the party moved briskly on until arrested by an opening in the Purbeck Beds, where Mr. Meÿer found a nice little fish about the size of a sardine, and everybody was immensely puzzled by a curious structure which nobody could explain.

The so-called Chilmark Quarries are situated in a ravine, drained by a stream flowing at right angles to the axis of the anticlinal. This natural ravine has been further enlarged, and its sides roughened, by the excavations of centuries. The east side is in Teffont parish, and the rector, Mr. Andrews, who has paid much attention to the geology of these parts, was kind enough to assist the Director in many ways. The following is an extract from the Circular, with reference to these quarries :—

"Junction of the Purbeck and Portland Beds well seen on the east side. A. Purbeck Beds. B. 1. Highest beds of the Portland series; 2. Chalky series with flints; 3. *Cerithium* and *Cyrena* beds; 4. Main building stone, a sandy limestone. Group 3 is very fossiliferous, and the shells well preserved."

Each group was taken in order, beginning with the highest. The

flint in the chalky series attracted much attention, being both vertical and horizontal in its mode of occurrence. Prof. Morris made some valuable observations on silicification in limestones, and Mr. Phillips collected specimens with a view to microscopic examination. A rather fine crustacean was found at the base of the chalky series, and a very large specimen in flint of *Avicula modiolavis ?* The *Cyrena*-beds, as usual, yielded the bulk of the fossils. Mr. Lilly, the lessee of the quarries, was very obliging in describing the varieties of the lower building stones, and ultimately some of the party accompanied him into the excavations on the west side.

Chicksgrove Mill Quarry was next visited. The junction of the Purbeck and Portland Beds occurs here under totally different circumstances, which the Director and Mr. Andrews took care to point out. Only a portion of the members went as far as Wockley quarry, and finally the party reassembled at Tisbury station to leave by the 4.32 p.m. train, going eastward.

EXCURSION TO CHARLTON, BLACKHEATH AND LEWISHAM.

APRIL 30TH, 1881.

Director:—J. LOGAN LOBLEY, ESQ., F.G.S.

(*Report by* THE DIRECTOR.)

As on previous visits of the Association to Charlton, the party at once proceeded to the great Chalk and Ballast pit to see the fine section showing the junction of the Secondaries and Tertiaries. This well-known section has been so fully described in the "Proceedings of the Geologists' Association,"* that it is only necessary here to state that the formations seen—the Chalk with flints, the Thanet Sands, and the Woolwich Beds—were described by the Director, who then led the way to the almost equally famous section at Hanging Wood Hill, displaying the Woolwich shell-beds. These at once attracted attention. The Upper and Lower Cyrena beds are very well developed and the shells, in good condition, may be obtained in abundance. The

* Proc. Geol. Assoc., Vol. iii., p. 205, Vol. iv., p. 528 and p. 557.

species are *Cyrena cuneiformis*, *C. deperdita*, and *C. cordata*. In addition to the Cyrenas the shell-beds yield amongst other species the gasteropods *Melania inquinata*, and *Cerithium funatum* in considerable abundance, but the "Ostrea bed" of the Ballast pit section thins out at this place. Overlying the shell-beds we find the "Plant bed," noticed by Mr. H. J. Johnston Lavis, F.G.S. in 1876, containing Dicotyledonous leaves and seed-vessels, but it is not nearly so well developed here as at Lewisham and Bromley

Ascending to the summit of the hill a very fine view over the Lower Thames Valley was obtained, and the river being filled with a high tide at the time the scene was particularly striking. The hilly and undulating ground on the south side of the Woolwich road contrasted with the quite flat marshes between the road and the river formed of alluvial deposits overlying the beds thrown down by the great fault running along the course of the road The old river bank was thus well seen, and it was pointed out tha while the top of the Chalk was twenty-feet above the level of the road on its south side it was upwards of a hundred feet below tha level on the other side.

A pretty Tertiary valley was now crossed, and on the summit o the opposite side the village of Old Charlton was reached, standing on the verge of the plateau of Oldhaven or Blackheath Beds which extends westward to the west end of Blackheath. The old mano house, built by Inigo Jones, looks over another of the indentation which fimbriate the plateau along its northern side. A temporary road section near Blackheath afforded an opportunity of noting the character of the Oldhaven Beds of this part of Kent, which consist of well rounded blue-black pebbles, imbedded in sand.

On reaching Blackheath, the party assembled around the shaf sunk for the purpose of investigating the cause of the subsidence which have occasioned so much anxiety and interest amongst the inhabitants of the neighbourhood. The first of these sinking occurred after an unusually heavy fall of rain on April 12th, 1878 but this attracted little attention compared with that caused by two others which took place in November last. Almost circula openings in the Heath were formed of a diameter of seven or eigh feet, widening bell-shape fashion below, and having a depth o nearly twenty feet. Arrangements had been courteously made to afford every facility to the Geologists by Mr. H. W. Jackson F.G.S., the Hon. Secretary of the Lewisham and Blackheath

Scientific Association, who are prosecuting the investigation, and awaiting the party was the Astronomer Royal, Sir George Biddle Airy. The Director having read an account of the subsidences and of the steps which had been taken to ascertain their cause from the *Engineer*, of February 4th last, Mr. Jackson stated the present position of the exploring operations, which consisted of the sinking of a shaft at one of the subsidences, and the careful examination of the material removed. A depth of 35 feet had been reached, and at this point water flowed into the excavation abundantly, and brought with it a large amount of sand. This had greatly impeded the progress of the work as almost constant pumping was required to enable the excavation to be continued. The pebble-beds not having been penetrated, the Woolwich Beds and the Thanet Sands would still lie between them and the Chalk. He had had the mound of fallen material carefully compared with the undisturbed surrounding beds, and had found a seam of red sandy clay exactly corresponding with such a seam in these beds, showing that the portion of the surface which had fallen in consisted of previously undisturbed material, and not of an artificial stopping of some old excavation. The conclusion he was led to by the observations so far made was that the sinkings were due to hydrogeological causes. He considered that the constant passing of water through the sand-surrounded pebbles and its outflow above the Woolwich Clays would carry away so much of the finer material as would cause a subsidence of the beds in places at first below and eventually at the surface.

On the other hand Mr. V. Holmes, F.G.S., who knows the locality well, was of the opinion that the sinkings were caused by ancient artificial excavations, similar to the "Grime's Graves," met with at various places in the western part of Kent.

After the thanks of the party had been given to Mr. Jackson, another of the sinkings was visited. This was found to be in an undisturbed condition, which gave it an interest of its own. A descent was made into the opening and the fallen material examined, when no difference could be perceived between it and the unfallen beds around, both consisting of the typical pebbles and sand.

The party now proceeded to Lewisham, passing, near the west end of the Heath, a good exposure of the Pebble-beds. At Loam Pit Hill, the Geologists again assembled, when this most interest-

ing and valuable section was explained. This section, like that at Charlton, has been fully described in these pages.* It shows the Chalk with Thanet Sands above considerably thinner than at Charlton, the Woolwich Beds better developed, the Blackheath pebbles reduced to less than a foot in thickness, and the Basement-bed of the London Clay with about, in one place, 20 feet of the London Clay itself.

The party returned to London from Lewisham Junction.

ORDINARY MEETING.

MAY 6TH, 1881.

W. H. HUDLESTON, Esq., M.A., F.G.S., President, in the Chair.

The Donations to the Library were announced as usual, and the donors thanked.

The following were elected Members of the Association:— Henry M. Platnauer, Esq., John D. Butler, Esq., T. Hay Wilson, Esq., and William Smith, Esq.

The following paper was read:—

ON CONIFERA. By J. S. GARDNER, Esq., F.G.S.

EXCURSION TO CROYDON, SHIRLEY, AND ADDINGTON.

SATURDAY, MAY 7th, 1881.

Directors:—JOHN FLOWER, Esq., M.A., F.Z.S., J. LOGAN LOBLEY, Esq., F.G.S., and H. M. KLAASSEN, Esq.

The Members of the Association having been joined, at East Croydon Station, by a number of the Members of the Croydon Microscopical and Natural History Club, the party proceeded eastward along the Upper Addiscombe Road, passing over the extreme western edge of the Oldhaven Beds and a small outlier of London Clay, extending northward from Park Hill. The sands of the

* See Proc. Geol. Assoc. Vol. iv., p. 528.

Oldhaven Series were well seen in one or two excavations recently made in digging foundations for new houses.

Near the southern end of Ashburton Road the party examined, by the kind permission of the occupier of the land, H. Johnson, Esq., two very remarkable springs in the side of the hill on the south side of the road—one at a point about 30 feet, and the other about 40 feet above the level of the road. The former of these, which is by far the larger of the two, is about 255 feet above the sea level. It has hollowed out for itself a considerable basin in the hill side, which has probably been increased artificially, and the stream flowing from it has cut out a considerable valley for itself. These features were here pointed out by Mr. Flower, who also explained the general structure of the hill, and of the Oldhaven and Woolwich and Reading Beds of which it was composed. He also stated that there were numerous similar springs along the northern side of this hill, forming some of the sources of the Wandle and the Ravensbourne. The general opinion is that these springs arise at points where clay beds, sloping to the north, come to the surface of the ground on the side of the hill, and there discharge the water absorbed by the large masses of overlying pebble beds; but, looking to the large quantity of water which is discharged from some of these springs, even in very dry weather, it seems not improbable that such at least have a direct connection with the large mass of chalk which extends southward up to the North Downs, and attains in some places a height of nearly 900 feet.

The party then proceeding towards Shirley House, the course of the watershed ridge, here very broad and flat, dividing the basin of the Wandle from that of the Ravensbourne, running through the grounds of Shirley House (courteously thrown open to the party by F. Banbury, Esq.), and along the edge of the fields on the west side of the Stroud Green Road, was described by Mr. Flower, who also pointed out a spot *on* the water shed ridge, in a ditch, about forty yards from the Stroud Green Road, where, in winter, a spring rises, from which the water flows eastward into the Ravensbourne, and westward into the Wandle.

After inspecting another fine spring and a small lake, the party proceeded, through beautiful plantations, to the Addington Hills, where the section of the lower beds of the Oldhaven Series at the back of the Sand Rock Hotel was inspected and was described by

Mr. Lobley, as also a pit excavated in the upper beds of the Oldhaven Series.

The Addington Hills form the northern escarpment of the Oldhaven and Woolwich and Reading Beds, which here attain a height of nearly 500 feet above the sea level. From the edge of the escarpment the chief physical features of the country, and the distant objects of interest, were pointed out by the Directors. Attention was particularly called to the small valley immediately at the foot of the hills, cut down into the chalk, and to the still larger valley between that and the South Norwood Hill, which is formed in the London Clay, the two valleys being, together, about four miles across. Mr. Flower suggested that probably this was once the valley of the ancient stream which came down the valley from Merstham ; while the deep valleys which run up into these hills were caused, in times long past, by the action of the springs similar to those already visited. The water shed between the Wandle and the Ravensbourne crosses these valleys nearly at right angles.

By the kind permission of the Archbishop of Canterbury Addington Park was next visited. A small lake fed by springs from the Pebble Beds, and situated in a deep valley cut out of them, was examined and described by the Directors, and the party then moved on to the Pinetum, where were seen some very fine specimens of *Abies Douglasii*, *Abies Menziesii*, and *Pinus Nobilis*. The " Fir Mount," overlooking Addington village and the site of a hunting seat much used by King Henry VIII., was the last point of special interest in the Park. From here fine views were obtained, embracing the high grounds of Worms Heath, four miles distant, which are capped with Pebble Beds, no doubt once continuous with those in Addington Park.

Proceeding down the steep face of the escarpment to Addington Village, situated on the chalk, the party returned home by the road on the south side of the Park. In the beautiful lane between Heathfield and Ballards the Wandle and Ravensbourne watershed was again crossed. At the Ballards Farm two remarkable blocks of sandstone, believed to be Sarsden stones, and lying on the chalk, were examined by the kind permission of Chas. Goschen, Esq. From hence the party returned, across the fields, to the East Croydon Station.

EXCURSION TO GRAYS.

SATURDAY, MAY 14TH, 1881.

Directors—Professor MORRIS, M.A., F.G.S., and HENRY WALKER, Esq., F.G.S.

(*Report by* HENRY WALKER, Esq.)

Joined by a large party of Members of the Essex Field Club, the company left Fenchurch Street station by the 2.25 p.m. train. The eastern outcrop of the small area of chalk which is found in South Essex, is first seen at Purfleet, where, on nearing the station, and looking to the left of the railway, an old and disused pit reveals both the chalk and a good capping of Thanet Sand resting on an isolated mass of it in the centre. Past the station, the bare sides of the great conical mound which is so conspicuous from the Erith side of the Thames, are close at hand.

Alighting at Grays Thurrock, the party were conducted along the high road leading to Stifford. Here were well seen the wide extent of the three southern chalk-pits at Grays, viz., the East Pit, the Central Pit (appropriated to the whitening manufacture, and the Western Pit, now occupied by the South Essex Water Company. Attention was called to the flooded condition of the Eastern Pit, which was explained subsequently. On descending to the Central Pit, one of the numerous Greywethers or Sarsen-stones, found at Grays was found lying on the unworked surface of the chalk on the horizon where the Thanet Sand had been breached. Professor Morris noticed its partially-rounded condition, which characterizes this, and many others Greywethers. Although the Woolwich Beds were wanting here, these were found about a mile further inland, and he suggested to the Essex Club an investigation at Stifford, where had been found a solitary instance of a certain shell in these beds north of the Thames. This was now in the Woodwardian Museum at Cambridge.

The abandoned Western Pit, in which the South Essex Water Company obtain their supply, was next visited, and Mr. Walker gave an account of the hydro-geology of the district. In the year 1861, the Chalk had been worked to the level of the spring in this pit over an area of about 60 acres, when attempts to go deeper led to the discovery of an abundant supply of pure water. The amount passing over the gauge every twenty-four hours was found

to exceed 2,100,000 gallons, and yet it was necessary, with five engines at work, to brick up fissures so as to keep the water down. The present supply for consumption in South Essex is 650,000 gallons daily, and nearly an equal amount is pumped to waste to avert inundation. No deep wells are needed, the water being found at the surface; the engine-house floor is only 17 feet above ordinance datum, and the water in the well varies from that datum to eight feet below it. To account for so large a volume of water in a district where the superficial pervious beds do not exceed ten miles in area, Mr. Prestwich extends the receiving ground to the Kentish Chalk, considering that the intervening Thames would not necessarily interrupt all the springs.*

After an inspection of the engine-house, the company were conducted to the high ground separating the Northern from the Southern Pits, from whence the physical structure of the surrounding country can be studied. Northward, the Langdon Hills with their capping of Bagshot Sand and Pebbles (388 feet) are the most conspicuous feature. Southward over the Thames, owing to the rise in the beds towards the Weald, a wholly different aspect is revealed. The absence of the Upper Tertiaries, the wide exposure of the Kentish Chalk, its dip-slope dotted in the foreground with wooded outliers of the Lower Tertiaries, as at Swanscombe and Cobham Mount, were successively pointed out and described by Professor Morris. At the conclusion, the thanks of the party were presented to Mr. A. W. Channer, Secretary of the Grays Chalk Quarries Company, Mr. Easton, C.E., F.G.S., and Mr. Anson, South Essex Water Company, and Mr. Philcox, for facilities and information kindly afforded.

EXCURSION TO SHEPPEY.

MONDAY, MAY 23RD, 1881.

Director—W. H. SHRUBSOLE, F.G.S.

The Members, numbering about 30, were met at Sheerness station by the Director and several other residents. After a pleasant drive of about nine miles, *viâ* Minster and Eastchurch, the cliff edge at Warden Point was reached about two o'clock. Five

* "The Water Springs in Grays." By Mr. Prestwich, F.R.S. Privately printed, 1860.

years before, when the Association visited this spot, the church was standing in rather dangerous proximity to the cliff. Since then it has been pulled down, and the materials have been removed to prevent them descending to the shore. The Director, in the course of a short address, spoke of the extensive waste of land that had occurred during the 30 years he had known the locality. He also called attention to the fact that whilst the fruits of endogens were very abundant, the fossil wood that came from the clay was exogenous. The absence of the endogenous wood might be accounted for by its incoherent fibrous structure, which probably caused it to float until decomposition took place. Getting down to the foot of the cliff, fossils were eagerly looked for amongst the shingle, pyrites, and fragments of septaria scattered on the beach and foreshore. Wood bored by *Teredo* was observed to be in abundance, and shark's teeth, crabs, fruits, and other things were found. The best specimen was a fairly good Chelonian, that fell to the lot of Dr. Foulerton. After a rough and slippery walk of five miles, the cliff-top was regained near East End Lane, where a good section of the Lower Bagshot Sand was examined; the junction with the London Clay below was found to be quite sharp and well-defined. Here, also, the changes that had taken place between the two visits of the Association, pointed to the conclusion that the land area of Sheppey had been considerably lessened.

The carriages that were in waiting took the party to Sheerness in time to dine at the Royal Hotel, when the Director, who stated that it was entirely owing to the Geologists' Association that he was led to turn his attention to scientific pursuits, took the opportunity of exhibiting the only palæolithic implement yet discovered in Sheppey, which was found by Miss Copland a few days before. Some large vertebræ, presumably cetacean, recently dug up near Minster church, were also shown.

The party left by the 7.50 up-train.

ORDINARY MEETING.

JUNE 3RD, 1881.

W. H. HUDLESTON, Esq., M.A., F.G.S., &c., President, in th Chair.

The donations to the Library received since the previous meetin were announced, and the donors received the thanks of the Ass ciation.

The following were elected members of the Association :—Georg Akers, Esq.; John Flower, Esq., M.A., F.G.S.; R. Jeffrey Hughe Esq., L.R.C.P.; Lieut. A. W. Macleod, Bengal Staff Corps; W J. C. Ross, Esq., B.Sc.

The following papers were read :—

1. "On a Continuous Section of the Oligocene Strata fro Colwell Bay to Headon Hill," by Prof. J. F. Blake, M.A., F.G.S

2. "On the Geology of the Vale of Wardour," by W. H Hudleston, Esq., M.A., F.G.S, President.

ON A CONTINUOUS SECTION OF THE OLIGOCENE STRATA FRO COLWELL BAY TO HEADON HILL.

BY PROF. J. F. BLAKE, M.A., F.G.S.

The arrangement of the Upper Eocene strata and the so-calle Miocene of the Hampshire Basin having been far from satisfactor one had, as it were, a sense of relief on receiving the high autho ity of Professor Judd to class the latter and some portion of th former under the term "Oligocene," so well known on the Conti nent. Now, the fauna of the Oligocene group is chiefly to b found in the so-called "*Venus*-bed" of Colwell Bay* (as far as th west end of the Isle of Wight is concerned), but the oth "Venus-bed" at Headon Hill contains rather the fauna of th Uppermost Eocene or zone of *Cerithium concavum*. This fact, fir made out by Prof. Hebert, and confirmed in greater detail by Pro Judd, immediately suggested the question, How then can the tw "Venus-beds" be identical, as they have alway sbeen supposed t be? Prof. Judd attempts to show that the evidence of their sup posed identity breaks down on examination, and suggests anoth

* "Ann. and Mag. Nat. Hist.," Ser. 2, Vol. vii., p. 14.

Fig. 1—Continuous Section from Colwell Bay to Headon Hill.

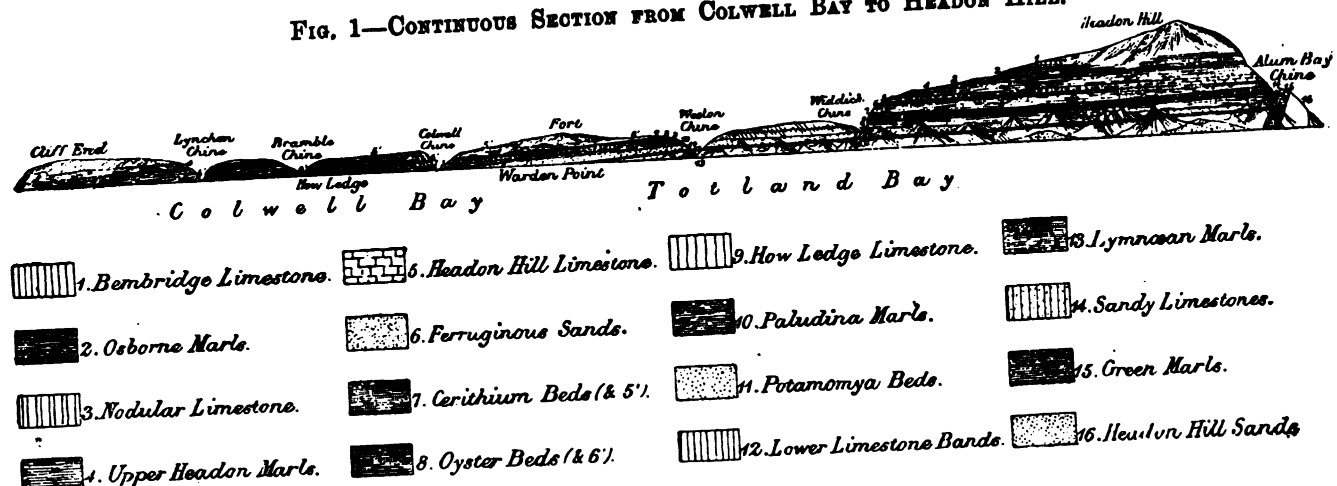


Fig. 2.—Section at Alum Bay Chine.

reading of the section as a more probable one which is as much as may be considered necessary, as if the two beds are *not* identical, it is a matter of minor importance what they each correspond to. These views having been attacked by Messrs. Tawney and Keeping, in a spirit quite unjustifiable in any scientific controversy, and the evidence on either side appearing to me insufficient, I took the opportunity of being near the locality in the winter of spending two or three days there, and of endeavouring, by dint of hard and somewhat muddy work, to accumulate sufficient of that sort of evidence which always appears to me to be most conclusive, namely, that of a continuous section, as far as possible, of the beds in question, to see how they change, and how they remain constant; and it is such a continuous section, with its results, which I bring before you this evening. Of particular parts of the section there are, of course, already admirable and very detailed descriptions, as of that at Colwell Bay, by Dr. Wright, and of that at Headon Hill, by Prof. Forbes and Mr. Bristow,* but these do not carry us from one end to the other; and in such changeable strata one may have too much detail. I have sought, therefore, rather to lay hold of the characteristics of larger groups, by which, being sufficiently constant, the latter may be traced over such a distance as three miles or so.

At Cliff end, on the north side of Colwell Bay, the uppermost strata seen *in situ*, marked 4 in my section, are a series of subferruginous marls and shell-beds, with great abundance of *Paludina lenta*. These are not very accessible in the winter, but may measure some 12ft. or so. Below this is a ferruginous-looking rock, underlain by false-bedded sands, only seen in the cliff, perhaps 2ft. in thickness. Next comes a series of beds, marked 5′ in the section, which may be divided, as was done by Dr. Wright, into five parts. They are sandy marls, limestone, laminated black marls, grey sandy marls, and dark green banded marls, but the whole is characterised by the abundance and variety of *Cerithium*, as also of *Cyclades*. If *Cerithium concavum* occur, it must be rare, for *C. margaritaceum* is the prevailing species. These *Cerithia* are to be especially noted, because, though they do occur at lower horizons, they are nowhere abundant except in this and the next succeeding division, where they are less so.

* "Mem. Geol. Surv." The Tertiary Fluveo-marine Formations of the Isle of Wight.

These three subdivisions rise gradually towards the summit of the cliff towards the south, and appear to become more sandy, till on both sides of the Bramble chine we have the full development of the so-called "Venus-beds." It is marked 6′ in the section, and may be more advantageously called the *Oyster beds.* It appears to be an exceedingly irregular mass, and not strictly divisible, the oysters and *Cythereæ* mingling, and extra-fossiliferous bands occurring here and there. The material is peculiarly black and sandy, and quite sufficiently distinct from the great majority of the beds forming the section to be recognisable if it retained the same character elsewhere. Now, beneath this series are seen some thin bands of stratified marl, with abundance of *Cerithium* and *Cyclas,* as in No. 5′, and a few feet of grey-brown unfossiliferous marls. It corresponds, apparently, to Nos. 10 to 17 of Dr. Wright's section. The relations of this part and consequent numbering will be seen hereafter. This seriesmay be seen at How Ledge lying on the next subdivision, and marked 9 in the section, and called the "How Ledge limestone." This is about three feet thick where first seen, and is full of *Lymneæ,* but with very few *Planorbes.* The bed below has its upper surface dark and crowded with fragments of *Lymneæ,* and a little further to the south, at the fort, the top 3ft. has become almost as calcareous as the limestone above; the black line with Lymnean fragments becomes only a parting between two beds of limestone, and contains rolled fragments of the lower part at this point. The oyster bed is still seen capping the cliff, but the underlying subdivisions are somewhat thickenėd.

Underlying the How Ledge limestone are about 20ft. of sandy marls, greenish at the top, and with abundant specimens of *Paludina* and several rarer fossils; towards the base, for about 6ft., the colour becomes a dark purple. This series, marked 10 in the section, is well exposed in the glacis of the fort, and is easily recognised by its lying between such well-marked beds as No. 9 and No. 11. It corresponds to Dr. Wright's Nos. 19 to 22.

Next comes the sandy series, marked 11 in the section, whose hardened cap forms the scar at Warden ledge, and is well seen at the south of the fort, on the northern boundary of Totland Bay. The upper part is false-bedded, and barely fossiliferous at first, the chief forms being *Paludinæ* and *Lymneæ,* but at the base are 6ft. of marls, with a black band of lignite in the middle; these marls are *crowded* with *Potamomya plana,* the whole mass being

sometimes made of this shell. This is particularly to be noted because, though *Cytherea* occurs in these marls, and *Potamomya* is found in fair abundance in higher beds at Colwell Bay, the latter nowhere so completely characterises the series. The line of lignite is an admirable guide, because, after tracing the beds already described in perfectly clear section to the north boundary of Weston chine, this band may be immediately picked up again without the shadow of a doubt in its right place on the south side of the gap of about 20 or 30 yards. It is this series which forms the whole cliff of Totland Bay between Weston and Widdick chines; and it may be continuously traced, with its *Potamomyæ* and its lignite band, for the first half of the distance. As far as Weston chine, the beds have been rising, but here they become horizontal, and before the boat-house is reached the lignite band is seen to decline and disappear beneath the slopes of turf, and the upper sandy part holds the cliff, and at this point has as many *Potamomyæ* as the marls below, so that they may be all classed together. Nevertheless, the hard band of the top is not exposed in the low cliff. The thickness of this series is about 20ft., increasing towards the south, so that the hard band is 17ft. or more above the lignite band. Some minor gaps in the turf expose the beds which lie below the *Potamomya* sands and marls here, and at the present moment (Jan., 1881), they may be still better seen in the slopes recently cut for grassing over on the north side of Weston chine. These, marked 12 in the section, consist of *a*, soft limestone band, 15in., full of black-coloured *Lymneæ*, *b*, unfossiliferous marls, from white to black, 3ft., *c*, thin limestone band, almost made of *Lymneæ*, &c., 6in., *d*, marls, 2ft., *e*, *Lymnean* limestone, 4in., *f*, grey marly sand, 2ft., *g*, black lignite band, with limonite and marls, ending in a solid ferruginous block below. All these may be characterised as Lymnean limestone bands. Nothing can here be now seen below the ferruginous band, though that occurs some height above the shore; but as the present portion corresponds to Nos. 26 to 30 of Dr. Wright's section, we learn from him that it is underlaid by greyish-white sands possibly 20ft. thick; but these are by no means the Headon Hill sands, which could only be exposed at low water in Totlands Bay. This will be seen when we get to Headon Hill. It cannot be doubted, however, that Prof. Forbes' section indicates these sands as Headon Hill sands, and very greatly exaggerates the anticlinal here. We have now to cross Widdick chine, which is the most critical point in the whole

section. Perhaps 100 yards intervenes between the observable exposures on the two sides of that gap, but the south side is much higher than the north, and we have to rise considerably to attain the level of the great Headon Hill limestone. Carrying the eye across the gap, from the sands of series 11, in a line parallel to the direction of the lignite band, and to the slope of the Headon Hill limestone above, these sands should occur just below the lowest of all the spots where the strata are not covered by *débris*, though nearly 100ft. above the sea level. Hence, if the guidance of the dip of the lignite bed is safe, these *Potamomya* beds ought not to be visible on the south side of the gap at this point. For these same beds to be the base and partly the representative of the Headon Hill limestone which suddenly comes on to the south would require a very rapid shift upwards in a very short space, of which the beds on neither side show any signs. Moreover, the sandy beds which underlie the Headon Hill sands contain no *Potamomyæ*, while they are abundant on the other side of the gap at the lower level. The lowest beds actually seen *in situ* here are green sandy marls, with lines of beautifully-preserved *Paludina;* in other words the series No. 10, just as it should be if we had a uniform dip. This is capped by a foot or two of soft *Lymnean* limestone, forming the broken top of a little cliff. This is the How Ledge limestone in its usual characters. *Immediately* above this comes a purple oyster bed, of about 16ft. in thickness, with fewer oysters than in that at Colwell Bay, and associated with *Cythereæ*, abundance of *Cerithia.* Above this the rocks become white with the profusion of the latter shells, of which *Cerithium concavum* is undoubtedly the most abundant. There are also many *C. margaritaceum* and *C. cinctum*, and *Cyclas obovata.*

These rocks are brown and green marls, most fossiliferous at the top and more laminated below, occupying a thickness of about 19ft. This succession seems so similar to that at Colwell Bay that one is tempted to jump to the conclusion that the two "Venus-beds" are identical, as has been always supposed, but it would be absurd to argue that they are identical because they contain similar common fossils when we have it determined by the researches of Prof. Judd that the faunas are remarkably distinct.*

* Messrs. Tawney and Keeping deny that the faunas are at all distinct, and it must be admitted, that if this were proved—*cadit quæstio;* but the gist of Prof. Judd's argument, as I understand it, is that the differences between the two faunas is just such as is characteristic of two wide spread horizons.

It has been noticed, however, that between the Colwell Bay Oyster-bed and the How Ledge Limestone are some beds full of *Cerithium*, &c., and grey-brown marls, with few but curious fossils, whereas here the oyster-beds lie immediately on the How Ledge Limestone. On the other hand, above the *Cerithium concavum* beds come deposits not found at Colwell Bay. The first is a mass, No. 6 in the section, of white and purple sands, with few fossils 8ft. in thickness, and this is followed by the great Headon Hill Limestone, No. 5 in the section.

Now, as there is no bed in Colwell Bay which must not undergo a great change to become this Headon Hill Limestone, one may be supposed to do so as well as another; and as we find on the one hand that the *Cerithium* and oyster-beds of Headon occupy a lower position in relation to the How Ledge Limestone, and contain a different fauna from those of Colwell Bay—which latter, on the other hand, occupy rather the place of the ferruginous sands below Headon Hill Limestone—it appears that stratigraphy lends its authority to the following proposition :—The Colwell Bay "Venus-bed" is *not* certainly identical with that at Headon Hill, but may occupy a higher horizon, the Headon Hill bed corresponding to the series intervening between the Colwell Bay bed and the How Ledge Limestone, and the Colwell Bay bed corresponding to the slightly fossiliferous sands immediately below the Headon Hill Limestone. It thus appears that a continuous examination of the cliff does not absolutely negative the distinctness of the two beds, which was the essential contention of Prof. Judd, though the great variation renders a positive proof difficult.

The limestone No. 5 is quite different to the How Ledge Limestone below, being much more rubbly and irregular. It is soft and divided into several beds of no constant thickness or character, and contains besides the *Lymnea* abundance of *Planorbes*. It has, when first seen, a thickness of 24ft., but by observing it consecutively along the escarpment from Widdick chine to Alum Bay chine it is seen to increase or decrease in thickness at the expense of the sands No. 6. These latter occasionally thicken to 12ft. or more, and then die away to 2ft. or less, while in the semi-circle which ends at Alum Point the limestones are seen suddenly to thicken from 24ft. on the north side to nearly 34ft. on the south, a distinct limestone mass being introduced lenticularly below. In the same traverse the *Cerithium* and *oyster*-beds can be distinctly

traced wherever accessible, maintaining the same general character and divisible into the same minor parts. Thus in the middle of the hills, beneath the sands No. 6, comes *a*, 8ft. 3in. green marls, with many *Cerithium concavum*; *b*, 5ft. 6in. of brown marls, with fewer fossils; *c*, 6ft. green marls, few fossils; *d*, 4ft. 6in. marls, with oysters and many other fossils, innumerable *Cyclas obovata* and some *Cer. concavum*; *e*, 3ft. green, less fossiliferous marls; *f*, 1ft. 6in. sandy marls, with fossils like those of *d*; *g*, 4ft. 6in. green, less fossiliferous earth; *h*, 1ft. 6in. brown carbonaceous earth; *i*, 5ft. brown and grey marls, with the *Fusi* and other usual fossils of the oyster-beds, but the *Cytherea* itself rare; *k*, 3ft. dark brown earthy marl, with similar fossils; *l*, 3ft. light yellow marl, with no fossils. The total thickness between the sands and the How Ledge Limestone is, therefore, about 45ft., but may be somewhat less; and it is obvious that we have the same two subdivisions into *Cerithium* and *oyster-beds*, though the line of separation may be arbitrary.

The How Ledge Limestone becomes very much better marked as we pass south, and forms a conspicuous feature in the cliff, the lower part having become as solid as the top, so that it presents the appearance of a 6ft. or 7ft. band of limestone divided by a dark band in the centre. Although the dip of the strata is seawards on the north side of Headon Hill, when the corner is turned they commence to rise in the cliff facing west, and we have hopes of taking up the lower beds again. Accordingly, at one or two spots, the succession below the How Ledge Limestone is uncovered. First appear some green marls only partly exposed, doubtless corresponding to the *Paludina* beds, because 20ft. down is seen the same hard sandstone block of Warden Point, about 2ft. thick, and 10ft. more are seen of purple marly beds, with the base full of *Cyclas* and *Lymnea* fragments, succeeded in a downward direction by 6ft. of yellow-grey sands, with a lignite band, and crowded with *Potamomya plana*; then some dark marl with these shells in lines, and 8ft. down a hard ferruginous band. The succession here, therefore, is perfectly in accordance with that at Totland Bay, where the same beds were last seen, and the upper part is seen still retaining its character where the How Ledge Limestone comes to a sudden termination at Alum Bay chine. I was not fortunate enough to discover any spot where the Lower Limestone bands of Totland Bay, No. 12 of the section, could be seen in the Headon

Hill—coastslips everywhere conceal it; but the ferruginous band mentioned above may possibly form part of them.

All sections of the Alum Bay end of Headon Hill that I have seen represent the beds as rapidly turning up to stand at a high angle there. In point of fact, however, they have not done so without fracture, and the junction of the horizontal beds with the nearly vertical ones is a line of fault, the effect of which is that the true succession is obscure. It is best described from the base, which consists of the well-known Headon Hill sands, No. 16 in the section, which are white below, and end upwards with 2ft. of bright yellow sand. At Alum Point, a very short distance to the north, these are seen horizontal. Next comes a 20ft. mass of green marls, very sandy, and containing few, if any, fossils. This appears to correspond to Nos. 32-37 of Dr. Wright's section, and is marked No. 15 in my section. Succeeding these are some sandy Lymnean Limestones in bands, with sands and marls between, the lowest band being remarkable for being underlain immediately by a thick dark ferruginous band, seen both at the chine and at the Point. The limestones are crowded with *Lymnea* and *Planorbis*, and fragments of these make up much of the marls between. These are 22ft. thick, and are marked No. 14 in the section. They are not very unlike the Lower Limestone bands No. 12, and there is a possibility that they may be the same. Above them comes 14ft. of grey sands, with scarcely any fossils, and then about 8ft. of green marl, becoming black at the top, and filled with Lymnean fragments. Against this bed, dipping at an angle of, perhaps, 60 deg. to the north, the How Ledge Limestones and the underlying green marls come plomb, only turning up for a yard or two at the junction. These marls and grey sands *should* be the *Potamomya* beds, if No. 12 and No. 14 were identical; but they do *not* abound in *Potamomya*, nor in any other shell. Nor is there the slightest sign of the hard sandy block of Warden Point, which has been seen to remain constant to within a short distance of this spot. I, therefore, think that these Lower Limestones are *not* the same as those seen in Totland Bay, though, in the absence of any clear section, this is not proved, and that the overlying sands and marls marked 13 in the section must be sought at the base of Totland Bay; in fact, that they are the bed No. 31 of Dr. Wright, recorded by him as greyish-white sand, in which he mentions no fossils. In either

case there is a considerable thickness between these Lymnean beds and the Headon Hill sands.

By climbing up the cliff face of Headon Hill towards the middle of the range, where the limestone is somewhat broken away, one may trace the upward succession from that bed to the Bembridge Limestone. There is, however, very little worth saying about it, as it has been so accurately described by Mr. Bristowe in the "Memoirs of the Geological Survey," before quoted. Immediately capping the limestone are some bluish-green clays, with bands of fossils utterly crushed, but apparently once *Paludinæ*. These may be the equivalent of No. 4 at Colwell Bay; it is 6ft. thick, and above comes about 24ft. of blue and red marls, in which no fossils were seen, the whole being only exposed in broken slips, and the thickness estimated on the slope. These two are marked No. 4 in the section. The next series, marked No. 3, consists, 1st, of a light sandy marl, 4ft. thick, and then a mass (12ft.) of nodular limestone, with very few fossils. Immediately on this comes the series No. 2, consisting at the base of 9ft. of yellow, brown, white, and black marls, with their beds full of *Paludina globuloides* (?), next of 9ft. more of similar marls, with fewer fossils, and finally about 40ft. (guessed) of blue and red marls, forming slips. These are obviously the Osborne Marls of Prof. Forbes, containing concretions, with *Lymneæ* and *Planorbes*. Finally, above all may be seen, when the pathway is reached, No. 1, the well-known Bembridge Limestone, somewhat sandy, and appearing false-bedded on weathering, with the usual fossils less common than in the Headon Limestones below. We do not, therefore, find any equivalents of the Colwell Bay Oyster-beds *above* the Headon Hill Limestone, though we cannot say that every yard is exposed.

If the above description and correlations be accepted, it is obvious that the Headon Hill series of Prof. Judd must end in the upward direction with the *Cerithium concavum* beds of Headon Hill, leaving out the Headon Hill Limestone, which becomes the fresh water representative of part of the marine Brockenhurst series, and thus becomes doubly anomalous. Nevertheless, it suits better with his separation of the series into two groups called Middle and Lower Oligocene, because almost immediately above the limestone come the blue and red marls so characteristic of the higher beds, part of which we should have to put with the Lower

Oligocene if the Colwell Bay Oyster-beds had been found above the Headon Hill Limestone. Both one and the other of these, perhaps, were produced by the same process. While the beds above and below are fairly widespread and uniform about the medium level of an estuary, these are limited and different, because when one part of the area went down to make the Brcokenhurst Marine Beds, the other, to make a balance, went up, and the purely fresh-water beds of Headon Hill were the result.

On the Geology of the Vale of Wardour.

By W. H. Hudleston, M.A., F.G.S., Pres. G.A.

I. Introductory.

The idea of writing a short paper on the Geology of this very instructive valley, originated in the difficulty of putting within the compass of an Excursion Report, the chief points of interest which arise even from a partial inspection of the locality. Those Members who shared in the recent excursion will have no difficulty in following me throughout the ensuing pages, and I trust that an inspection of the accompanying map may be of some assistance to such as only know the Vale of Wardour by repute.

We obtain most of our early geological information from Fitton ("Trans. G. S.," 2nd Ser. Vol. iv., p. 248), whose remarks are of the greatest value, both as to stratigraphy, and to geological details in the quarries. The diagrammatic section on page 165 is slightly altered from one given by him.

The very scarce Catalogue by Miss Benett (printed at Warminster in 1831 for private circulation), contains some notes regarding Tisbury, and an admirable description, as far as relates to the Purbeck beds is given by Brodie in his "British Fossil Insects." Of late years one of the most important publications, having reference to this district, is the "Portland Rocks of England," by Prof. Blake ("Q. J. G. S.," Vol. xxvi., p. 199).

Altogether, therefore, we may regard the Vale of Wardour as classic ground, and much which I shall have to say this evening is more or less known to some of you; yet this is a difficulty which is apt to meet everyone who attempts to deal with the geology of an attractive district. Fortunately there is a considerable amount of difference in the quarry sections now from what there was in

Fitton's time. Moreover we have the justification of Fitton himself with reference to the Portland-Purbecks of the Isle of Portland, that the quarries should be examined and reported on from time to time. There are also, certain points in dispute which, if we cannot clear up this evening, we may at least endeavour to offer some suggestions by way of attempting a solution.

An explanation of the topography is an indispensable preliminary to a correct understanding of the subject, and I must therefore request your attention to the accompanying sketch map. The Vale of Wardour may be described as an inlet from a much more extensive vale lying to the westward, and the mouth of this inlet between the bold Greensand ridges of East Knoyle and King's Settle, is about three miles in width, across an expanse of Kimmeridge Clay. A line drawn between these two points would correspond with a low watershed, which limits the basin of the Nadder, and forms the boundary between Wilts and Dorset. The average elevation of this watershed may be about 300ft., and the sharp promontory of King's Settle rises very abruptly above it to a height of 750ft. This forms the southern gate-post of the Vale of Wardour, and is a conspicuous object from most points. Semley station is almost on this watershed, and not very far from the foot of the hill.

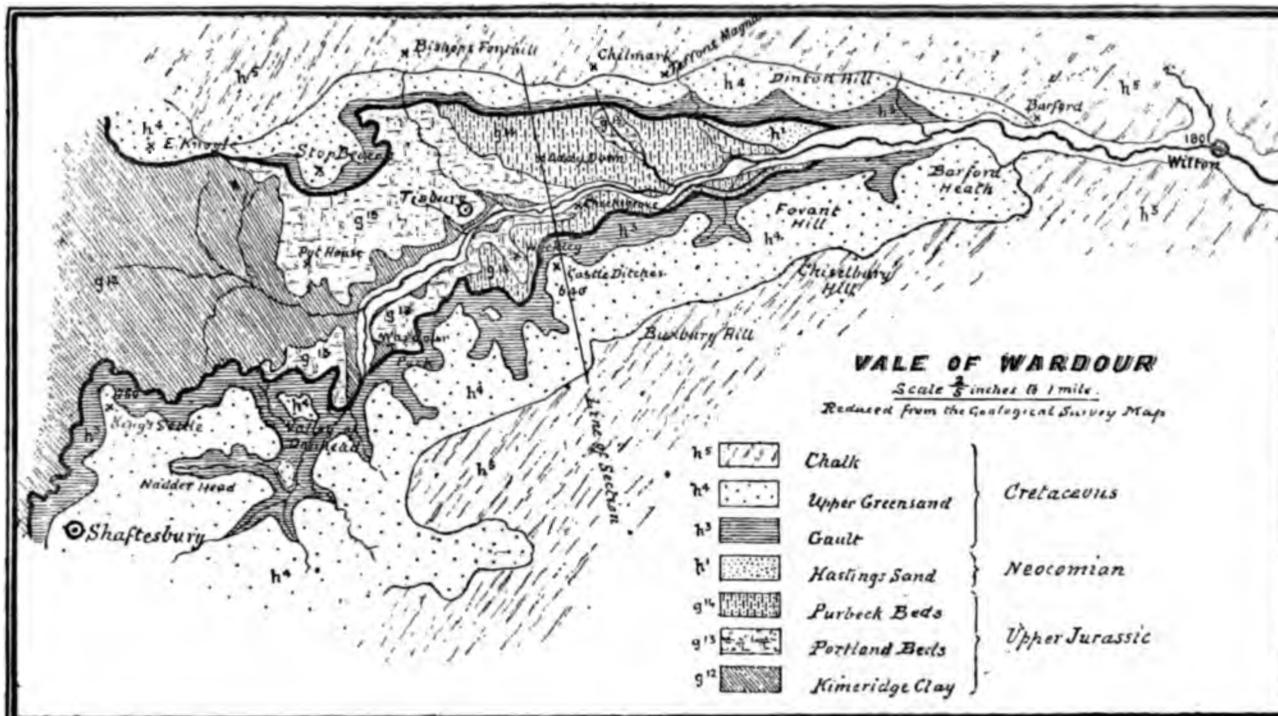
FIG. 1.—MAP.

Note in explanation of the accompanying Map.

The principal object of the map is to show at a glance the very marked double unconformity at the base of the Cretaceous system. This is accentuated by the strong black line at the base of the Cretaceous beds throughout the Vale of Wardour. 1st—This line rests upon a continuously ascending sequence of Jurassic Beds in advancing from west to east. 2nd —Different beds of the Cretaceous base rests upon the line in an ascending sequence from east to west.

The Vale of Wardour is a complete hydrographic basin, the accumulated waters converging to the eastward in the river Nadder, which joins the river Wiley at Wilton, 180ft. above sea level.

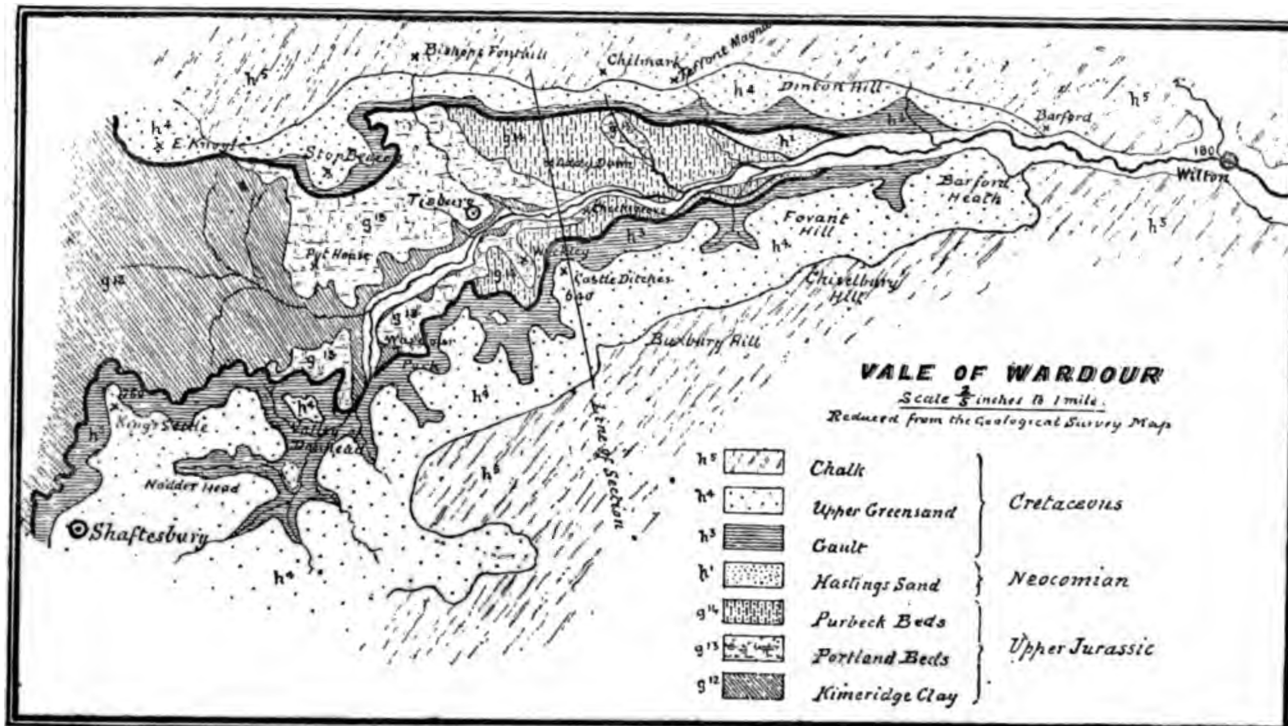
The three principal quarries showing the junction of the Portlands with the Purbecks are, (1)—Wockley Quarry (also called Shaver's Bridge Quarry) marked with a ×; (2) Chickgrove Mill Quarry, in the map marked × Chicksgrove; and (3) the Chilmark Quarries, partly in Teffont parish, which occur in the large Portlandian inlier to the east of Lady Down.


VALE OF WARDOUR
Scale 2/5 inches to 1 mile.
Reduced from the Geological Survey Maps
h5 Chalk
h4 Upper Greensand
h3 Gault
h1 Hastings Sand
g14 Purbeck Beds
g13 Portland Beds
g12 Kimeridge Clay
Cretaceous
Neocomian
Upper Jurassic
Bishops Fonthill
Chilmark
Dinton Hill
Barford
Wilton
Barford Heath
Fovant Hill
Chiselbury Hill
Buxbury Hill
Castle Ditches
Tisbury
Pyt House
Stop Beacon
E. Knoyle
Kings Settle
Nadder Head
Shaftesbury
Line of Section

The King's Settle may be regarded as the western termination of the long ridge of Greensand on the south of the Vale, and it is also the highest of the numerous blocks into which this formation has been cut up by the transverse valleys so frequent on this side. The adjacent block is known as Ticklepath Hill; it contains circular earthworks. Then comes the great valley of Donhead nearly transverse to the main course of the Vale; the principal stream of the Nadder rises in one of its branches. The next heights are those above Wardour Park; then comes the deep inlet of Wockley Vale, completely at right angles to the main valley. Flanking this deep lateral valley is the salient point of Castle Ditches—on the line of section. There is an immense system of earthworks here, of which an accurate account has been given by Sir R. Colt Hoare, but of its history and of those who made the works there seems to be very little known. Eastward of this again are smaller lateral valleys, and the Greensand ridge is continued in the wooded heights of Sutton and Fovant, as far as Barford, where the Vale of Wardour proper may be said to terminate in a blunt apex of Greensand, which is observed to plunge beneath the chalk at a considerable angle about half-way between Wilton and Dinton stations. From this point to the line of watershed previously mentioned, near Semley station is about twelve miles, and this may be described as roughly the length of the Vale, though Fitton regards the valley of the Nadder from Barford to Wilton and the valley of the Wiley from Wilton to Salisbury as part of the Vale of Wardour. It is through this valley, now wholly in the chalk that the accumulated waters of the Nadder basin flow, but still in the same direction. At Salisbury, (150ft. above sea) several rivers converge, and the drainage escapes through a transverse gorge in the chalk at right angles to the mean direction of the Nadder valley.

The Greensand ridge on the north is almost equally cut up by transverse valleys, and forms a series of wooded and rather peaky heights. That above Dinton, forming part of Teffont Common, is a very handsome hill. And then we have Ridge, through which the section (Fig. 2) is drawn; and most conspicuous of all Stop Beacon and Fonthill, which, from many parts of the Vale, shut out the Greensand heights of Knoyle, that form the north-western gate-post, facing the point from which we started—viz: the King's Settle.

The Vale may be described, geologically, as a Jurassic picture set in a Cretaceous framework, and the most richly sculptured border of that framework is the Greensand, whose topography


VALE OF WARDOUR
Scale 2/3 inches to 1 mile.
Reduced from the Geological Survey Map
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Cretaceous
Neocomian
Upper Jurassic
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Chilmark
Teffont Magna
Dinton Hill
Barford
Wilton
E. Knoyle
Stop Beacon
Tisbury
Pyt House
Barford Heath
Fovant Hill
Chiselbury Hill
Castle Ditches
Buxbury Hill
Line of Section
King's Settle
Shaftesbury
Nadder Head

ment or stratigraphy. It is obvious that these two factors relate to different periods of geological time, and must be considered separately. By the aid of the map and the diagrammatic section you already know with what formations we have to deal. There are no Tertiary Beds within the area, and the Superficial Deposits are not of any great importance; though there are some clayey gravels immediately west of Dinton station, which might repay a closer attention than they have hitherto received.

II. The Formations.

g^{12}. The Kimmeridge Clay is the lowest bed in the district. It forms the low ground of the western portion of the Vale, and the bottom of the Nadder Valley, as far as a little east of Tisbury. Not much is known about it in this immediate neighbourhood, which is to be regretted, since beds of widely different age, containing very distinct groups of life forms, have, in this country, been lumped under the general heading of Kimmeridge Clay. Nor is there any satisfactory information as to its thickness hereabouts. Some of you may remember that the Kimmeridge Clay near Weymouth has a thickness not far short of a thousand feet, whilst at Oxford it does not exceed 70ft. Therefore inference is of very little use in estimating the thickness of so uncertain a formation.

g^{13}. The Portlandian Beds come next in order, and constitute by far the most interesting group in the district, as they are the most valuable in an economic sense. The basal portions, which immediately rest on the Kimmeridge Clay, constitute a crumbly mixture of lime, sand, and clay, with some hard bands, and above these comes the Portland Stone, which has been quarried all round Tisbury, on both sides of the river, for ages. An immense quantity of stone has been got out from quarries that are now more or less filled up, and this must help to account for the varying reports received as to the Portland Beds of this district.

The chief area occupied by this formation lies to the west of Tisbury, where it constitutes some high ground in the direction of Newtown and Pyt House; the surface of this part of the country conforms to the curve of the beds, which are squeezed up by the anticlinal, whose axis here occurs very near to the northern edge of the Portlands, just beneath the woods of Fonthill. There is a "gravel pit" (so called) on the summit curve of the Portlandian bulge, which is in fact a mass of Portland stone decomposing *in situ*, with the flinty portions remaining as undissolved fragments,

the whole being in great confusion, but without evidence, as far as I could see, of having been transported from any considerable distance. This material is at present worked for road stone, and contains, along with other siliceous fossils, the celebrated " star flint " in considerable abundance.

The spot whence *Isastræa oblonga* was formerly obtained would appear to have been in a field north of Tisbury, on the Fonthill road. With reference to this Miss Benett says (*op. cit.*, p. 4), " The Siliceous madrepore of Tisbury is a subordinate bed in this (the Portland) series, and which has not yet been found elsewhere, with the exception of the agatized madrepores of Antigua: they were first discovered by being turned up by the plough; but the sinking of a well near the inn at Fonthill Giffard has proved their geological position to be over the Portland rocks; they are extremely local." The following postscript is added :—" Geological position of the siliceous madrepore. The sinking of a well in the field called Butcher's Knap, in the parish of Tisbury, the only place where the Coral Flint has been found, and which led to the discovery of the bed. The usual rubble of the Portland Beds in Tisbury, ten feet—Siliceous Madrepore, one foot—The usual succession of the Portland beds in Tisbury, forty-two feet—Water —No sand between the beds." When we come to consider the subdivisions of the series given below, there will be no difficulty in fixing the geological position of *Isastræa oblonga*, and the notion that it has been derived from beds above the Portland rock—an idea based upon Miss Benett's first statement—is wholly erroneous.

The subdivisions of the Portland Beds of the Vale of Wardour, with approximate thicknesses, are given below. As the whole of them are to be found in one section in the neighbourhood of the Chilmark ravine, between two and three miles E.N.E. of Tisbury, it is to those quarries that we must direct our attention.

Subdivisions of the Portland Beds of the Vale of Wardour, with approximate thicknesses.

Below a thin dirt bed of the Purbeck Series.

No. I. Upper *Cyrena*-beds (Upper Building Stones), 18ft.; fine-grained, very white, siliceous limestones of low specific gravity, frequently of a peculiar oolitic texture, also travertin-like, and

* The *formations* of the Vale are described from below upwards; the *subdivisions* of the Portland formation from above downwards.

often vacuolar. The general appearance of much of this rock is that of a more or less fresh water limestone, similar to the immediately overlying Purbecks, but there is an abundance of Portland fossils, occurring as vacuous casts throughout, though the chief line of fossils is about 7 feet below the dirt bed. We noted *Cerithium portlandicum* (c), *Neritoma sinuosa* (r), *Chemnitzia*, sp. (r), *Cyrena ? rugosa* (c), "*Sowerbya Dukei*," *Cardium dissimile*, *Trigonia gibbosa* (c), *Lucina portlandica*, *Perna*, dwarf form, *Pecten lamellosus*. This, then, is a Portlandian fauna of the *Cyrena* type, where, as a rule, the common fossils, and especially the Monomyaria are much reduced in size. With certain important differences it may be regarded as a repetition of No. 3, presently to be described. This stone has been much prized for building, and immense quantities have been formerly extracted, partly, I believe, by means of galleries. The restorations in the west front of Salisbury Cathedral, where there is some very delicate carving, have been executed in this class of stone. The lower portions of No. 1 are described by the proprietor of the quarry as "mongrel," and to this circumstance may be attributed the fact that they are at present obscured by *débris*, so that the junction with the underlying subdivision is not seen.

No. 2. The Chalky Series, 24 feet. This has abundance of flints* both in beds and in fissures throughout the upper half, but none in the lower half. It is burnt for lime, and is remarkable for very large Portlandian fossils, including *Am. boloniensis*; thus representing the truly marine type in contradistinction to the *Cyrena* type of Portland Beds, which immediately prevails above and below it. *Trigoniæ* belonging to two groups occur in considerable numbers, and at the base there is, in some places, an immense accumulation of *Trigonia gibbosa*, which may be referred here or to the next subdivision. Crustacea of considerable size occur in the chalky series, which also contains some of the fossils of No. 3, besides the following scarce forms, which do not seem to occur in the other Portlandian Beds of this district, viz., *Pholadomya tumida*, Ag., *Thracia* peculiar form of *incerta*, Thurm., *Cardium calcareum*, Bl., *Cardium*, small variety of *Pellati*, De Lor., *Avicula ? modiolaris*, Rœm., and *Ostrea minor*, De Lor. The scarcity of Gasteropoda is an especial feature.

No. 3. The Ragstone, or *Cyrena*-beds 8-10ft. This is by far the

* *Flints*. See Appendix A, page 180.

most interesting of all the groups, and contains an immense number of fossils, usually rather small. The Monomyaria, especially *Perna*, occur in stunted forms, there are no Ammonites, but a varied and somewhat peculiar assemblage of Gasteropoda is perhaps the most marked feature of the whole. *Cyrena rugosa* is the characteristic fossil, and occurs in great numbers, especially in the lower beds. *Cerithium concavum*,* Sow., is the most abundant univalve, but there occur *Natica incisa*, Bl., and more rarely small specimens of *Natica elegans*; *Chemnitzia teres*, sp. n., *Pseudomelania percincta*, sp. n., *Neritoma sinuosa*, Sow. (c), *Nerita transversa*, var. *minor*, De Lor., and two species of *Actæonina*.† Of the bivalves we note a *Corbula*, one or two species of *Corbicella*, small variety of *Lucina portlandica*, *Cyprina pulchella*, *Cardium dissimile* (small), and many others, some of which may be new, as the fossils of these beds have, on the whole, the indications of a peculiar facies.

It is not intended in this paper to give very close details of any of the series. These particular beds are best studied in the Chilmark ravine, where an attentive examination will soon show considerable differences of development. And if this be the case within the space of one set of quarries, a much greater difference will obtain over a more extended area. In the vicinity of Tisbury, and for some distance to the west, No. 3 is pretty near the surface, and helps to form some of the rubble covering the building stone. It is overlaid in places by a bed very full of *Trigonia gibbosa* and *Mytilus jurensis*, in a loose earthy deposit, which no doubt represents the irregular *Trigonia*-bed, noted in a corresponding position at Chilmark. The chalky series has entirely gone out at Tisbury.

This same No. 3 forms a strong bedded impure limestone, somewhat similar to the group below, and this distinguishes it, in the quarries, from the chalky series above; yet its more intimate composition has perhaps almost as much affinity with the chalky series, since, though largely charged with fine quartzoze sand, there does not appear to be any glauconite. No Portland rock in England contains its fossils in such an admirable state of preservation, nor is there any other place where the *Cyrena*-type of beds occurs at the base of the main limestones in such a marked state of development. With reference to this subject I may observe that what I have called, simply for the sake of illustration, the *Cyrena*-type,

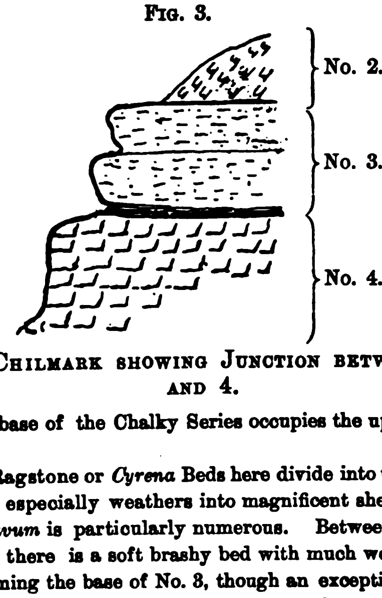
* Quite distinct, of course, from the Tertiary species of the same name.

† For further information respecting the Gasteropoda of this group of beds, see "Geol. Mag." for September, 1881, page 385 *et seq.*

that shell being frequently associated with *Cerithium*, represents a peculiar "estuarine" condition, which was the precursor of the Purbecks, and is generally to be found, as in the case of No. 1, at the top of the Portland Stone.

No. 4. The main building stone—say 18ft. This is *the* Portland Stone of the district; the country all round Tisbury and to the west, is seamed with quarries, old or new, where these beds have been worked. At Chilmark and Chicksgrove extensive galleries exist whence the stone has been extracted. The roof of these galleries consists of the basal bed of No. 3, usually full of *Cyrena*. Further westwards the building stone crops out, and in some places is covered by a rubble made up of silicified fragments in which the *Isastræa* is found. I think the evidence seems to point to the fact that the *Isastræa*-bed lays at the top of this series, somewhere about the junction with the Ragstone (No. 3), and it is not improbable that some destruction of the beds may have occurred before the fluvio-marine, or *Cyrena* series (Ragstone), was laid down. This may account for the absence of the chalcedonic layer further to the east. The subjoined section in the face of the N.W. quarry at Chilmark confirms this view.

FIG. 3.



SECTION AT CHILMARK SHOWING JUNCTION BETWEEN NOS. 2, 3 AND 4.

No. 2.—The base of the Chalky Series occupies the upper portion of the section.

No. 3.—The Ragstone or *Cyrena* Beds here divide into two main blocks, of which the lower especially weathers into magnificent shell tablets, in which *Cerithium concavum* is particularly numerous. Between this fossiliferous series and No. 4 there is a soft brashy bed with much wood. This may be regarded as forming the base of No. 3, though an exceptional development, and it seems to rest on a slightly uneven surface of

No. 4.—The building stone series.

The palæontology of the building stone series is simple. There are but few fossils, and those mostly of the large Portlandian types. *Am. boloniensis* and *Trigonia gibbosa* may especially be noted, the latter sometimes in a state of chalcedonic replacement. Most of the chalcedonic casts of fossils picked up about the country come from these beds, nor is there much difficulty in recognising the cherty-looking flint of this horizon from the much blacker flint of the chalky series. In some places there is a thick bed of *Trigonia gibbosa* towards the top.

The lithology and economic history of No. 4 offer us points of greater interest than does its fauna. Commencing from the top, we have the Trough Bed, the Green Bed, the Pinney Bed, the Hard Bed, and the Fretting Bed. The Trough Bed is the best. It was tested by the Commissioners appointed in 1839 to select the stone for the new Houses of Parliament, who describe it as a siliciferous limestone, with a specific gravity of 2·48, containing—

* Silica	10·4
Carbonate of Lime... ...	79·0
Carbonate of Magnesia ...	3·7
Iron and Alumina	2·0
Water and Loss	4·2
	99·3

Like all the rest of No. 4, the Trough-bed has abundance of quartz grains ; but there may be a certain amount of opaline silica forming a cement. This might account for some of the water found in the analysis. The Green and Pinney Beds are also limestones full of quartz grains, and contain a considerable amount of glauconite in amorphous granules and a very considerable quantity of spongeous-looking siliceous fragments, which are snowy and opaque, and remind one of the siliceous dust in the interior of flints. The Pinney Bed is penetrated by a small *Serpula*, from whence the name is derived. The Fretting Bed is an earthy, fine-grained, sub-calcareous rock, the quartz grains apparently constituting one half of the mass. The whole series might be described as quartzose limestones with some glauconite. I have seen sponge spicules in

* See Appendix B, page 184.

some of the beds, and Mr. Andrews has flints from this horizon which are loaded with them.

Besides Salisbury Cathedral, the highest in England, the following are some of the buildings where this stone has been used, either for construction or restoration: Wardour Castle, Fonthill Abbey, Chichester Cathedral, Romsey Abbey, Chapter Houses of Westminster Abbey, Rochester Cathedral, Balliol College, Oxford, &c., &c.

It is not at all improbable that there may be considerable variation in the quality of the stone within short distances, since we have that from Tisbury described as a calciferous sandstone of a greenish brown colour, weighing 111 pounds per cubic foot, and that from Chilmark as a siliciferous limestone of a light greenish brown, weighing 153lbs. per cubic foot; but these, in point of fact, may represent different beds. Some of the stone worked at Wardour, probably low down in the series, is almost a Greensand.

No. 5.—The Basement Beds—say 38ft. In the Chilmark quarry these are not seen, but a well section gives 36ft. to water, which may be taken as pretty near the mark.

The upper portions of these may very probably represent some of the more sandy building stones of the country between Tisbury and Wardour, in which case deduct 6ft., which add to No. 4.

Being in a rotten, crumbly condition where exposed to atmospheric influences, there is no good section, and the natural outcrops are obscured by the falling over of the stone above. There is a cutting on the roadside between Tisbury and Wardour (near Haselton), and one or two bad exposures near the above mentioned cutting, from which the following estimate was formed of the beds below the building stone :—

(a) Loose sands, with doggers, presenting the appearance of having lost their calcareous matter...	7 ft.
(b) Greenish concretionary Limestone Grit, with occasional lydite ;—originally a *Trigonia*-bed	3 "
(c) Loamy sands and clays	21 "

The hard band (*b*) contains numerous badly-preserved fossils which bear a general resemblance to the large Portlandian type. It is believed that the following were recognised: *Trigonia gibbosa*, several varieties; *Trigonia* (clavellate), *Mytilus jurensis*, *Perna Bouchardi* (very large), *Pecten lamellosus*, *Avicula credneriana*,

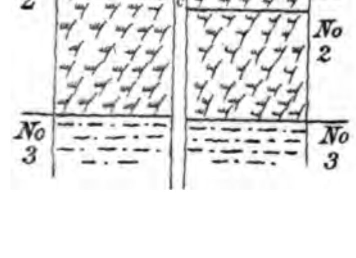
Exogyra bruntrutana, *Astarte* or *Cyrena?* *Cardium dissimile*, *Natica elegans*.

Prof. Blake speaks of having found hereabouts blocks of rock containing a remarkable series of fossils; but it is presumed that he cracked them all up, as none have since been seen with that peculiar assemblage. Making allowances for the state of conservation, there really seems very little difference between this fauna and that of No. 4. It is what one would call an average Portland stone fauna of the large type, somewhat modified.

Summary of the Portlandian Rocks.—The five sub-divisions above detailed form the outcrop in reverse order as one approaches from the westward, in this respect conforming to the regular ascending sequence so conspicuous in the Jurassic rocks of the Vale of Wardour. No. 5 forms the escarpments to the west, and No. 4 the surface of a large part of the western area; but as we come eastwards traces of No. 3, and eventually the sub-division itself, are manifest in the quarries about Tisbury. None of these beds are directly covered by the Purbecks. Coming still eastwards, we catch sight of No. 2, or the chalky series, in the quarry at Wockley, covered by Purbecks, and going north-eastwards, we arrive at No. 1 in the Chilmark ravine, also covered by Purbecks. We thus recognise the evident fact that the Purbecks rest upon an unconformable surface of Portland Rocks in the Vale of Wardour.

A comparison of the quarries in the Chilmark ravine (east side, in Teffont parish), and at Chicksgrove Mill—points about 1½ mile distant—will show this very clearly. See section annexed:—

FIG. 4.



A. Part of the section in Chilmark quarry; *a*, Dirt Bed intervening between No. 1 (Upper Building Stone or Portland Oolite) and the overlying Purbeck Beds. *B.* Part of section in Chicksgrove Mill Quarry, 1½ mile S.W.; *b*, the lowest Purbeck Bed; *c*, the highest Portland Bed, cemented into one block which projects over the remainder of No. 2.

In this case it is not difficult to see, that at Chicksgrove, No. 1 has disappeared entirely, together with the upper or flinty half of No. 2. The loss of beds is equal to about 30ft., and to compensate for this we have, at Chicksgrove, about 2ft. of a limestone literally crammed with large Portlandian fossils *(c)*, which may well be called the *lamellosus*-bed. The contrast between this and its strange yoke-fellow *(b)* is most complete.*

This latter (*b*) is a fissile limestone without the sign of a shell. It has, in parts, a sort of travertin-like look, and yields in the more cleavable portions *Ophiopsis pencillatus* and *O. breviceps*, together with imperfect specimens of *Archæoniscus*. These occur quite low down (the thickness is about 2ft.); towards the top of the block are traces of Cyprids. No idea can here be entertained of a passage between Purbecks and Portlands: the discordance is most complete, and thirty feet of beds are missing, whether through denudation or non-deposition is not easy to say, but I incline to the former explanation. That this state of things is not a mere local accident is clear from the junction section at Wockley (now known as Shaver's Bridge Quarry) being identical. The chief difference there is, that, whereas at Chicksgrove the specimens of the Purbeck fishes are poor in the junction bed, at Wockley they are in a better state of preservation.

g^{11}. The Purbeck Beds are estimated by Mr. Andrews at about 70ft. in this district. Good sections of the basal beds are obtained at Wockley and Chicksgrove, especially the former, somewhat reversing the case in Fitton's time, when the latter quarry showed the best sequence. The section of the bottom beds at Chilmark does not correspond with those in the two last-named quarries. This has sometimes given rise to a suspicion that the very marked discrepancy between the uppermost Portlandians at Chilmark and Chicksgrove is in some way connected with this want of correspondence between the lower Purbecks in these two quarries respectively.

A carefully-measured section by Mr. Andrews of the Purbecks at Wockley shows about 28ft. of beds. This section is cut deeper into the hill, and displays more Purbecks and less of the Port-

* There is a block of stone in the Jermyn Street Museum, in which the junction of the Purbecks and Portlands is said to lie, containing Cyprids in the higher part. It has doubtless been derived from Chicksgrove or Wockley.

lands than in Fitton's time. There is a strong S.E. dip, and the upper beds are much troubled by curvature. The highest beds in this quarry are very full of *Cypris*. Towards the centre is a strong black dirt band, about 2ft. thick, and this now forms the highest bed at Chicksgrove, where, some 20 years ago, part of a coniferous tree 26 inches in diameter was obtained. Further to the east are some sections in higher beds. At Teffont a quarry in a cement-like limestone called "lias" has yielded Mr. Andrews some interesting fishes—*Microdon radiatus*, *Pleurophilus*, and a small pycnodont palate, besides the valves of a large *Estheria*. Not far from Dinton Station the "lias" is being quarried in a wood. Above this are beds which contain *Trigonia densinoda*—a new species recently described by Mr. Etheridge (Q.J.G.S., vol. xxxvii., p. 247), together with squeezed casts of other bivalves of considerable size.*

The lithology of the Purbeck series is usually that of a fissile or travertin-like limestone, with softer intervening marls, the whole weathering into an argillaceous and very damp soil. There is, however, much concretionary oolite, and some peculiar structures, whose origin is by no means clear, besides abundance of *Cypris*-marls, &c. Impressions and casts of *Cyrena* and *Cyclas*, &c., are numerous in some beds, but good specimens of shells would seem to be rare.

h^1 The Hastings Sands.—In the section near Dinton Station the junction of these with the underlying series is not very clear, but the reddish sands with *Endogenites erosa* are in force for a short distance. The Survey Map represents the series as thinning out on the west, so that it is already lost beneath Castle Ditches (see diagrammatic section), but Mr. Andrews thinks there are traces of it in certain ferruginous lumps at the foot of that hill. If this be so, Fitton was correct in showing the Hastings Sands in his section, and they must be continued a little further westwards.

h^3 and h^4 Gault and Greensand.—The base of the Cretaceous System is represented by a clayey margin, nowhere here, I believe, exceeding a thickness of 75ft., and probably thinning to the westward, as the Greensand of Knoyle overlaps it even in this area, where it rests upon the Purbecks, which, as we have seen, produce a damp soil, so that the difference in vegetation is not very obvious. This strip of Gault has, however, a very marked effect on the sur-

* See section by Mr. Andrews, Q.J.G.S., vol. xxxvii., p. 252.

face when contrasted with the overlying Greensand, as it serves to hold up the water which percolates the more porous formation. The very extensive woods clothing the flanks and spurs of the Vale generally extend down to the Gault, and the fine oak timber which it yields affords an appropriate contrast to the numerous pines which shoot out from the sides and summits of the Greensand.

According to Dr. Barrois, this Greensand forms the lower portion of the zone of *Am. inflatus*, the remainder of the zone being characterised by loosish sands, capped by a band of harder Greensand with *Exogyra conica*. Above this comes the zone of *Pecten asper*, corresponding to a portion of the Warminster Beds. That fossil is abundant on the slopes north of Castle Ditches. Near Teffont Mr. Keeping has discovered a new species of *Siphonia*, which he has deposited in the Woodwardian Museum.

Part of this Upper Greensand of the West of England is on the horizon of the Upper Gault of Folkestone, whilst the Gault of this district may represent the Lower Gault of that well-known section. It seems pretty clear that the Gault of Lyme Regis is Lower Gault. But at Blackdown there is no Gault, and the zone of *Am. inflatus* rests directly on the older rocks, thus showing a double system of unconformity. Such also is, in fact, indicated in the sketch map, where the strong dark line shows not only the unconformity of the Cretaceous Beds to the underlying formations, but brings out clearly the changing character of the cretaceous base itself.

h^5 The Chalk hardly comes within the limits of the district examined during the Excursion except as a formation seen in the distance, whose escarpments on either side form the outside border of the framework of the picture.

III. Stratigraphy, &c.—Having thus briefly considered the nature and composition of the several formations, we must next endeavour to ascertain something of the history of their present arrangement and sculpture. To do this thoroughly would be a task of considerable difficulty, requiring more time than is now at my disposal. I will therefore simply touch on the more salient features which must force themselves upon all students of geology who visit the Vale of Wardour.

These phenomena are capable of being divided, as regards time, into two distinct groups. The first group of phenomena relate to a pre-cretaceous period, the second to a post-cretaceous one. The

latter is by far the most important in the more obvious nature of its results, but the agencies which prepared the seabottom, on which the basement beds of the Chalk, or Upper Cretaceous were deposited—so clearly indicated as they are in the Vale of Wardour—claim at least a passing notice.

Pre-cretaceous changes.—Before proceeding to the consideration of this part of the subject we should ascertain what there was to alter. In the Vale of Wardour itself there cannot be much difficulty on this score, but it is impossible to say how far the Purbeck-Portlands, which are in such force here as a limestone formation, extend beneath the Chalk to the south and to the north. They certainly re-appear in great force in the Isle of Purbeck, 30 miles to the south, and in a lesser degree at Swindon, 35 miles to the north. At present we can only conjecture as to their continuity, though the very great differences of development at these three points makes one somewhat doubtful on the subject. But the question of non-deposition can hardly apply in the Vale of Wardour, where the Portlands terminate on the west in a strong escarpment, so that the very remarkable overlap, indicated by the strong dark line on the map, must in the main have been due to pre-cretaceous denudation.

Taking the northern side of the valley; at Dinton the Cretaceous base just touches the last remnants of the Hastings Sands, whilst further west, as near Chilmark and Ridge, it reposes upon the Purbecks. Opposite the conspicuous heights of Stop Beacon and Fonthill Abbey it rests upon the Portlands, and at Knoyle, the north-west gateway of the Vale, the Greensand rests directly on the Kimmeridge Clay. As we proceed further westward, beyond the limits of the map, the Cretaceous System rests upon an ever descending geological horizon till in the Blackdowns, the base there wholly arenaceous, reposes on the New Red Marls.

There can be no agent which has produced this state of things other than one which has shaved off the tops of all the beds in succession, and the only agent we know of, capable of doing this kind of thing, is the sea. That we have here an old plain of marine denudation will be conceded by most geologists, such being, as Professor Ramsay observes,* the invariable result when a country is gradually sinking at a rate proportionate to the rate of waste

* "Physical Geology and Geography of Great Britain"—cf. also De Rance, "Geol. Mag.," 1874, p. 248.

by the waves. The only question is as to the time when this took place. It will be readily believed that during Purbeck-Wealden times much of the S.W. of England was above highwater mark, and must therefore have had some sort of sculpture. Probably the margin of the Wealden basin in these parts was not very far west of the line of the diagrammatic section. East of this line the waters grew deeper, west of it the land would gradually increase in elevation. Towards the close of the Wealden period the great easterly depression reached this western land. It gradually sank and its features were effaced. Each successive portion in turn must have remained an area of destruction rather than of deposition, whilst in the meantime the various members of the Lower Greensand were being deposited in other regions, principally to the eastward.

Post-cretaceous changes.—The anticlinal is by far the most important stratigraphical feature of the district, and its effects are especially visible in the character of the landscape. Its two wings have a very different angle. That to the south is generally stated at about 5°, and that to the north at from 15°—20°. This circumstance combined with the steady easterly dip before mentioned serves to give a general S.E. inclination to a large portion of the Vale, since the southern wing occupies so much more surface than the northern one. The escarpments also, especially those of the Chalk, are much steeper on the south side, where the beds are flatter, than where they roll over at such a considerable angle, as on the north. The diagrammatic section shows this peculiarity fairly well; it is very noticeable from such a point as Castle Ditches.

Throughout the whole of its course below Tisbury the valley of the Nadder has been excavated, not in the axis of the anticlinal but considerably to the south of it. Doubtless the upcurving of the strata, by causing a line of weakness somewhere, had a share in determining the direction of the valley, the excavation of which has been effected by meteoric agencies. The general question of its sculpture, which probably began in Middle Tertiary times, it would be quite impossible to discuss in a paper, which has already exceeded the limits originally intended, but the effects of "rain and rivers" are by no means ended. The springs which rise in the neighbourhood of the base of the chalk escarpments are not long in cutting through the softer Greensand, but are better

held up by the Gault. In this way the very interesting lateral valleys are mainly produced, but in such a case as that of the ravine below Chilmark, and also in other instances, there may be flexures at right angles to the main flexure acting as a predisposing cause. In the same way the irregularity of some of the Greensand buttresses may be partly due to carving out, partly to cross folding.

The anticlinal itself belongs to a system of flexures which govern the physical character of a large portion of the South of England. The Weymouth anticlinal presents features similar to this one, in that its axis approaches the northern margin of its dome with much the same results as here, viz., that the southern slope is gentle, whilst that on the north is so sharp that the beds decline to follow suit, and the great fault at Ridgway is the consequence. That line of disturbance passes through the Isle of Purbeck and thence into the Isle of Wight, where some of the finest stratigraphical phenomena in our islands are produced by it. Omitting minor folds the Vale of Wardour anticlinal is the second of this system of arches having an east and west strike. It is probably continued eastward through the chalk country, thus passing into the well known axis of Winchester. This again belongs to the same line as that, which, with far more energy and complexity of folding, has produced the great oval swelling of the Weald. Towards the north there is the parallel axis of the Vale of Pewsey, but it does not bring up the Oolites. Still the same phenomenon of sharp dips to the north are observable in this case.

To recapitulate — there are three main anticlinals of post-cretaceous age in the South of England, viz., that of Pewsey on the north, supposed to be a continuation of the axis of Artois in Picardy ; secondly, this one of Wardour, which is probably continued eastwards in the axis of Winchester, and partly in that of the Weald, of which the axis of Bresle, in France, may be a continuation. Thirdly, there is the Weymouth anticlinal, which, in the Isles of Purbeck and Wight becomes the most energetic of all, and is most likely to be traced across the channel in the well known uplift of the Pays de Bray.

Many questions present themselves for consideration in connection with this interesting subject, such, for instance, as the probable age of these disturbances, and also the effects of the far older post-Carboniferous elevation. The Mendips are not very far

off, and a continuation of their axis would pass underneath the chalk a little to the north of Stonehenge. We may, therefore, regard the Vale of Wardour as lying parallel to, but a few miles to the south of the probable position of the old axis. This is a question of some importance with reference to its effects on many of the secondary rocks, more especially those of the Upper Oolites within this area.

There is just one point more to consider, viz., why in all these cases the north wing of the anticlinals should be the steepest. This fact has been held to prove that in all these movements the beds have been thrust from the south towards the north, and this law would appear to prevail very extensively throughout Europe north of the latitude of Cape Finisterre.* All movements of this class are undoubtedly due in the first instance to the shrinkage of the Earth's crust consequent on the contraction of the nucleus by secular cooling. An anticlinal therefore is not the result of a thrust from below, but represents one of the undulations of an envelope forced into wrinkles by the contraction of its support, and we thus arrive at the apparent paradox that these local upheavals are the result of a general sinking of the crust.

But if we plunge into the depths of terrestrial physics this paper may never come to an end ; I will merely observe, therefore, in conclusion, that whether we regard the stratigraphical lessons which it teaches, or the palæontological treasures which it contains, there are few spots in this England of ours more attractive than the Vale of Wardour, or one more worthy of being visited by geologists.

APPENDIX A.

Note on the Flints collected during the excursion :—

The Lower Purbeck and Portland Beds in the Vale of Wardour contain a considerable amount of flint, which is distributed for the most part in layers more or less interrupted.

The flints of the Portland Beds are most numerous in the upper part of the chalky series of Chilmark and Chicksgrove, but there is abundance of a more cherty variety in the Building Stone series (4 of the general section).

Professor Morris and Mr J. A. Phillips were much interested in the occurrence of these flints, and the latter ultimately selected

* Macpherson—Uniclinal structure, p. 24.

three specimens for further examination. Of these No. 1 is a flint from the lower part of the Purbecks in Chilmark Quarry. No. 2 is a flint from a horizontal layer in the upper part of the Chalky Series in the same quarry; whilst No. 3 is from a vertical layer at the very top of the Chalky Series. In the accompanying plate, Fig 1, represents part of a slice cut from No. 1, magnified 55 diameters; and Figs 2-6 represent parts of a slice cut from No. 3, the vertical flint, variously magnified.

Examination of the slices. No. 1 (The Purbeck Flint) has been cut so as to exhibit within the slice (¾in. diam.) three varieties of structure of about equal area.

The first and slightly largest area presents a somewhat brecciated appearance, which, when viewed by reflected light reminds one very much of a number of pieces of old dirty ice floating about in a pond and frozen together again on the formation of younger ice. These pieces represent portions of the marly limestone which has become silicified, but with retention of a certain amount of its original character, whilst the purer chalcedony which has sealed them together represents an infiltration into spaces which may have been formed by the contraction of the original mass, and subsequently enlarged by the action of solvents. A few oolitic granules, a fragment of shell, some valves of *Cypris*, and certain forms which may be organic, make up the rest of this picture.

The middle portion of the slice represents that part of the pond where the old ice had been the most melted and where in consequence its character had been the least preserved. This part of the slice, therefore, is more translucent, but presents fewer objects of interest.

The third portion is remarkable for the quantity of oolitic granules (see figure), yellowish by reflected light, immersed in a more or less pure chalcedony. A lake of very pure chalcedony intervenes between this area and the rest of the slice. This completes the evidence as to the flint having resulted from the silicification of calcareous matter. The oolitic granules have the structure common in oolitic rocks. They are sometimes compound, but usually not so; and are generally oval, with, for the most part, a well defined periphery. There has been the usual deposition of calcite round a granular nucleus or pellet, producing an external fibrous crystallization, the nucleus itself being, as observed by Mr. Sorby*

* Anniversary Address, 1879, Q.J.G.S., vol. xxxv, p. 80.

with regard to the oolitic grains of the Purbecks, relatively large. Plate I, fig 1 represents four of these granules.

No. 2. The Portland Flint from the horizontal layer. This slice, when viewed with a low power and reflected light, shows a greyish blue and slightly opalescent ground mass, more or less flecked with yellow spots and dull brown markings. When viewed with a higher power and transmitted light a general dulness is noticeable, especially in connection with the brown markings. Otherwise the appearances, as regards the fragmentary character of the mass, are much the same as in many limestones. There are, for instance, plenty of shell fragments, sponge spicules, and other pieces showing evident structure—some very curious indeed—many of these are distinct in outline and leave no doubt as to their nature, whilst others are shadowy and seem more confused with the general mass, which contains here and there an oval oolitic granule. The specimen is from a solid and nearly homogeneous flint; there are no lacunæ of agate or of vitreous quartz, and the whole is so far obscured, either by an extensive deposit of opal silica or by included impurities, as to show but little traces of crystalline structure, except at certain points. On the whole, although perhaps there is no absolutely convincing evidence, yet the appearances are in favour of this flint having been the result of the silicification of a calcareous rock.

No. 3, Plate I, Figs. 2-6. This slice consists of two very distinct portions. The larger portion (A) in general character much resembles No. 2 in its dull grey opalescent ground mass with yellow specks and brownish suffusions, and is very imperfectly crystalline. With a general resemblance to No. 2, there are important differences. Thus at one end of the brownish spotted ground mass there is an inlet of agate silica (Fig. 5 by reflected, Fig. 6 by transmitted light), with fortification bands, and a lake of quartz in the middle. The sides of this inlet show the fibrous crystallization of chalcedony. Into this inlet of agate silica there projects a promontory of the brownish coloured (by transmitted light) ground mass, which is so far clear in its structure as to resolve itself into a number of pale brown disks, gradually becoming closer until their outlines seem merged in the general ground mass. It is these closely fitting pale brown disks, producing for the most part a general suffusion, which constitute, as far as appearances goes, one of the principal differ-

ences between this flint and a limestone. Otherwise we notice abundance of organic fragments of shell, sponge spicules, &c. There are two very fine branching spicules in A. One of these (Fig 3), showing three arms in the section, is possibly that of an hexactinellid;* its axial canal is filled in with the yellowish opaque matter similar to that forming the specks previously mentioned. In an adjacent portion of A, less highly magnified (Fig 4), may be seen a spicule almost eaten away by the enlargement of its axial canal.

The second and smaller portion of the slice (B) is very different. A complete description of this would be a very long story. Only some of the more obvious conclusions can be stated here. Seen with a low power and by reflected light, a very confused and somewhat agate-like pattern prevails, the opaque portions being either brownish red from the presence of iron, or milk-white. By transmitted light with a higher power portions of this peculiar pattern are seen to be sections of rhombs (Fig 2) which must at one time have consisted of calcite or dolomite. The interior of some of these rhombs now consists of vitreous quartz, whilst the walls are opaque from iron, or the milk-white chalcedony, which probably contains some opal silica. In other cases the appearances are such as to render it possible that some calcite may yet remain. This part is also dotted over with the brown disks, but here their edges are, for the most part, defined, and the radial structure is more obvious. The confluence of such brown disks produces a great increase of opacity.

When we remember that this slice represents a portion of a vertical layer of flint, the appearances detailed above become capable of, at least, a partial explanation. A small fissure in the chalky limestone is infiltrated with calcite, but after a time siliceous deposition became the order of the day, and a pseudomorph of some form of silica after calcite is the result. But side by side with this there was silicification in another form, of which we see traces in the numerous brown disks, which, it appears to me, are only sections of a radial growth of chalcedonic silica, intertwined perhaps with opal silica; when this growth has a definite periphery, it may be deemed spherulitic. This appears to be a sort of disease to which

* Professor Sollas, on seeing a rough drawing of the spicule section, writes that "it is more suggestive of tetractinellid than of hexactinellid affinites: the former are usually shallower water dwellers than the latter."

the limestone is subject, and is somewhat analogous to the formation of Beekite. But when, in a massive limestone, under powerful pressure, such an action has been set up, the spheres have been rendered so confluent that oftentimes all traces of anything like a spherulitic structure are obliterated.

Time will not permit me to pursue this interesting subject further, but on the whole this slight examination of the Portlandian Flints serves to bear out the views of my immediate predecessor in the chair as to the replacement of limestone by silica in some form.

APPENDIX B.

The following table is extracted from those given in the Commissioners' report, and gives the chemical analysis, &c., of a few of the principal building stones compared with Chilmark stone:—

Name of Stone.	Mineral designation of Stone.	Silica.	Carbonate of Lime.	Carbonate of Magnesia.	Iron, Alumina.	Water and Loss.	Specific Gravities.	Absorbing Powers.	Cohesive Powers of 2-in. Cubes.
									lbs.
Chilmark	Limestone siliciferous	10·4	79·0	3·7	2·0	4·2	2·481	0·053	25·553
Portland	Oolite	1·20	95·16	1·20	0·50	1·94	2·145	0·206	7·590
Bath Box	Do.	...	94·52	2·50	1·20	1·78	1·839	0·312	5·313
Mansfield	Sandstone.	49·4	26·6	16·1	3·2	4·8	2·338	0·151	18·216
Park Nook	Magnesian Limestone	...	55·7	41·6	0·4	2·3	2·138	0·295	15·433

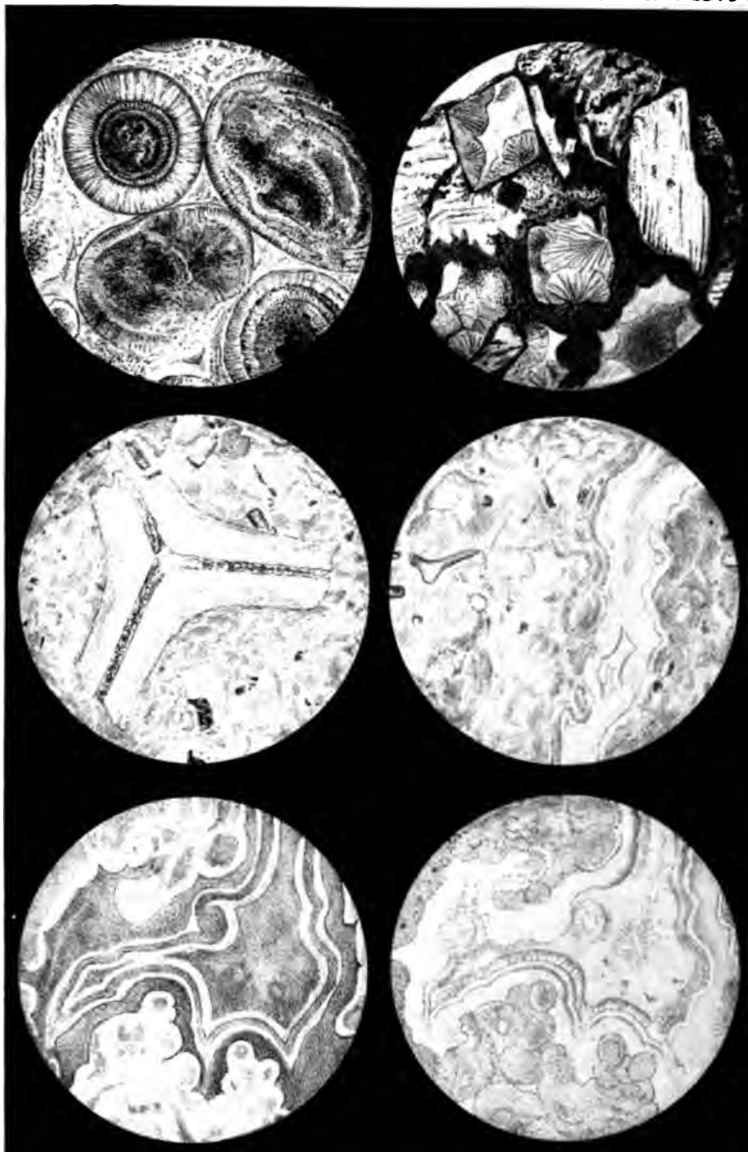
The general excellence of the stone from the Chilmark Quarries would, it is said, have induced the Commissioners to recommend it for the construction of the Houses of Parliament, had not the cost of the stone at that time, owing to the absence of railway communication (4s. 6d. per foot cube, delivered in the Pool of London), precluded its being used.

The above has been communicated by Mr. Lilly, the lessee of the quarries, to whom the members of the Excursion are greatly indebted for information and assistance.

EXPLANATION OF PLATE I.

Fig. 1.—Slice of a Purbeck flint, from the Vale of Wardour, showing sections of four oolitic granules. By transmitted light; magnified 1 X 55.

[redacted]



1. 2

3 4

5 6.

Frank Rutley del. A. S. Foord lith. Mintern Bros imp.

1 × 55. 2 × 35. 3 × 120. 4 × 25. 5 × 18 (reflected light). 6 × 18.

Sections of Purbeck and Portland Flints, Vale of Wardour.

Fig. 2.—Slice of a Portland flint, from the Vale of Wardour, occurring vertically in the chalky series—Portion B—To show the pseudomorphs after calcite or dolomite, and the radial crystallisation of silica. By transmitted light; magnified 1 × 55.

„ 3.—Part of the same slice—Portion A—To show section of a sponge spicule. By transmitted light; magnified 1 × 120.

„ 4.—Another part of the same slice—Portion A—To show the general character; sponge spicule, fragments of shell, &c. A vein of chalcedony towards the right. By transmitted light; magnified 1 × 25.

„ 5.—Another part of the same slice—Portion A—To show the inlet of quartz, lined with agate-like bands of chalcedony, which here penetrates the general mass. By reflected light; magnified 1 × 18.

6.—The same. By transmitted light.

EXCURSION TO THE EAST END OF THE ISLE OF WIGHT.

WHIT-MONDAY, JUNE 6TH, AND TWO FOLLOWING DAYS.

Directors:—PROF. J. MORRIS, M.A., F.G.S., F. G. H. PRICE, ESQ., F.G.S., AND E. B. TAWNEY, ESQ., M.A.

(*Report by* E. B. TAWNEY.)

The party arrived at Portsmouth by the mid-day train, and forthwith took passage in the steamer for Ryde. From hence a short railway journey brought them to Brading Station.

The first item in the programme was to visit the excavations at the Roman Villa. Accordingly the party, guided by Mr. Price, proceeded on foot to the Villa. A printed account of the discoveries was given to each member, while Mr. Price conducted the party round the works, explaining the plan of the original building, pointing out the mosaics in the different rooms, the hypocaust, &c., and finally the well, which had just been re-excavated.

Returning to Brading Station, the members found awaiting them the little train which had been sent for them by R. B. Grantham, Esq., M.Inst.C.E., and H. S. Freeman, Esq., the Consulting and Resident Engineers of the Bembridge reclamation works.

A few minutes brought the party to New Harbour Works, where they were met by the above-named gentlemen, who indicated the points of interest in the scheme by which a great tract of

land is being drained and reclaimed. The new sluices, which were near completion, were examined.

The party then walked along the bank which has been built to form the sea-wall to Bembridge Hotel, which was to be head-quarters; and the luggage was sent across by boat through the kindness of the manager of the works.

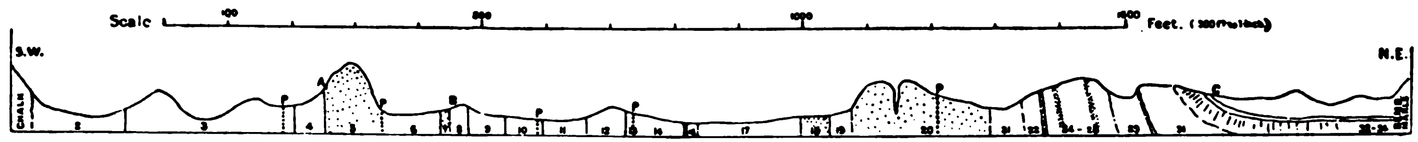
WHIT-TUESDAY.—Mr. Freeman having kindly put his steam yacht at the disposal of those who preferred a sea voyage to a walk on foot to White Cliff Bay, some half-dozen members availed themselves of his kind offer. White Cliff Bay was not, however, a favourable place for landing, and they had to disembark with bare feet, and wade a short distance, arriving after the foot passengers.

The party then observed the coast section. Beginning at the east end of the Bay is seen the Chalk forming the headland of Culver Cliff, and rather inaccessible on this side. Lying against it, with the beds at first nearly vertical, are the red clays of the Woolwich Series, without fossils. Next, the London Clay, about 300 feet, was examined; at the base is an interesting conglomeratic basement-bed, containing pounded pebbles; and next the mottled red clay, &c., a few feet above which is seen a greenish-brown sand, in which *Ditrupa plana* is abundant. Succeeding the London Clay is the Lower Bagshot Series, in which a mass of fragments of leaves is seen at one spot, but nothing entire was obtained. The Bracklesham beds are fairly fossiliferous in places, as described by the Rev. O. Fisher; but there was not time for the collection of these fossils, which, when obtained, are so difficult to preserve. In the Barton Clays nothing was found; nor could the party collect anything from the yellow sands of the Upper Bagshot, though officers of the Geological Survey here found casts of *Cardium* and other marine shells. Above the Upper Bagshot Sands were seen the fresh-water clays of the Lower Headon, in which ordinary fresh-water univalves are abundant; over these are occasional lignite beds a few inches thick.

Lying on the eroded surface of the green fresh-water clays are marine beds of the Middle Headon; the lowest two feet have been known since Mr. Fisher's paper (1862) to contain the Brockenhurst fauna, *i.e.*, the same fossils that occurred in such abundance in the railway cutting in the New Forest in a bed only one foot thick.

By W. TOPLEY, Esq., F.G.S., Geological Survey of England.

SECTION OF WHITECLIFF BAY (After Prof. J. Prestwich) SHOWING VARIOUS CLASSIFICATIONS OF THE BEDS.



Geol. Sur.: Woolwich & Reading Beds. : London Clay. : Lower Bagshot. : Bracklesham Beds. : Barton Clay. : Upper Bagshot. : Lower Headon : Middle Headon : Upper Headon : Osborne or St. Helens. : Bembridge Limestone.

FLUVIO-MARINE SERIES.

LOWER EOCENE. .... MIDDLE EOCENE. .... UPPER EOCENE.

J. S. Gardner { London Clay. Lower Bagshot. Bournemouth Freshwater Beds. Bournemouth Marine Beds.

Bracklesham Beds of Rev. O. Fisher.

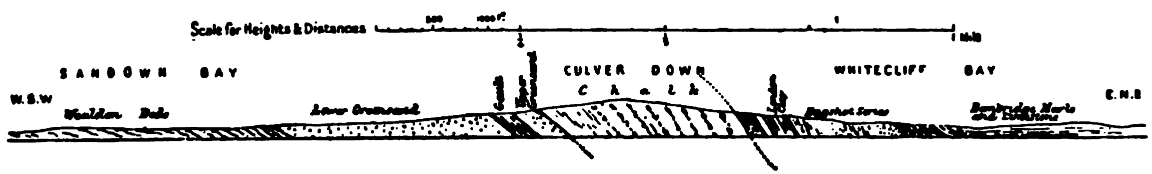
Prof. J. W. Judd { Headon Group (Estuarine). Brockenhurst Series (Marine). Lower Bembridge Marls. Bembridge Limestone.

LOWER OLIGOCENE. MIDDLE OLIGOCENE.

The numbers of the Beds are those used by Prof. J. Prestwich (Quart. Journ. Geol. Soc., Vol. ii, plate ix, fig 2.)

A.—Horizon of Plant-Beds in Alum Bay.
B.— „ „ at Bournemouth (Gardner).
C.— „ Crustacea and Insects at Gurnet Bay.
P.—Lines or Beds of Pebbles.
The Chief Beds of Sand are shown by dots.

SECTION FROM SANDOWN BAY TO WHITECLIFF BAY.



Above this bed fossils became scarcer for a few feet, but some 14 feet higher up is a rich band in the Middle Headon containing abundant *Cytherea incrassata*, *Cerithium pseudocinctum*, and other fossils characteristic of the same beds at Headon Hill, many of which were obtained by the members. After the Middle Headon there is a change again to fresh-water conditions in the Upper Headon, and the thin limestones near the top, crowded with fossils, attracted attention. These are succeeded by the mottled red and greenish clays of the Osborne series, which are apt to be grassed over in the cliff, but can be seen on the shore.

More attention was paid to the Bembridge Limestone, of which massive blocks strew the foreshore; it is a cream-coloured and often concretionary limestone, and contains *Lymnea*, &c. Just at this period of the afternoon the rain began to descend, and advantage was taken of a rock-shelter formed by an overhanging ledge of Bembridge Limestone.

The walk over the rest of the series round by the Foreland was in rain, and very cold rain for that time of the year. The most fossiliferous places on the foreshore for the Bembridge Marls were still covered by the tide. However, the thin marine *Ostrea Vectensis* band near the base, about five feet above the Bembridge Limestone was well seen in the cliff; but after that nothing was picked up. The Gravel of the Foreland was passed in rain, but its continuation had been examined nearer Bembridge.

After dinner a vote of thanks to Messrs. Grantham and Freeman was passed for the kind arrangements which they had made for the reception of the party.

WEDNESDAY.—In the morning the party walked to Sandown Bay by the Granite Fort to examine the Weald, the Neocomian and succeeding beds up to the Chalk.

At the top of the Weald the Perna-bed was found, *i.e.*, loose blocks of it were seen lying about, owing to the tumbled state of the Wealden cliffs. The Weald first exposes mottled red beds, which occupy the shore for some distance; then the grey shales succeed, and these are rich in *Cypridea Valdensis* towards the top, while interstratified with them are limestones showing a brackish water condition, containing a dwarfed oyster, a small *Modiola*, *Cyrena media*, &c., as on the Atherfield coast.

Except in the Perna-bed, no fossils were found in the Neocomian, though a great thickness is exposed under Redhill Battery, consisting of grey sandy clays, yellow and brown sand rock, &c.

Above the Neocomian follows the dark grey Gault clay; but neither the upper nor lower junctions of this clay are well seen now, and no fossils were found. The Upper Greensand seems to pass insensibly into the Gault, and the micaceous marls and sandstones at the base are poor in fossils. The glauconitic sandstone above has the true Upper Greensand characters, and the fossils are more abundant. The Chloritic Marl here can scarcely be made into a separate division, phosphatic nodules and fossils being the same as in the Greensand.

There was no time for working further round the point. Indeed the Chalk could only be examined at low water, or in fallen blocks.

A return was made up the zigzag path which leads past Redhill Battery, and so by Yaverland Manor House back to Brading.

The beauty of the scenery on a lovely morning compensated for the wet walk of the previous afternoon. The party returned to London by an afternoon train.

EXCURSION TO HIGHAM, KENT.

JUNE 18TH, 1881.

(Report by the Director, W. WHITAKER.)

The object of this excursion was to examine some cuttings on the railway through the Hundred of Hoo, which have laid open good sections of the Lower Tertiary beds. The excursion was probably the first in which the sections to be seen were as new to the Director as to those who trusted to his direction.

We were met at Higham Station by some gentlemen of the neighbourhood, amongst whom was the Rev. C. H. Fielding, of Higham, who kindly placed his knowledge of the country at our service. Our progress was also much aided by Mr. H. Russel, of Cliffe, by whose good offices we were carried along the line by a contractor's engine and truck, and so enabled to see all that the sanguine author of the programme (who was not present) had proposed, which could not otherwise have been done.

It may be better to describe the cuttings from west to east, without regard to the order in which they were actually seen, merely remarking that the district is part of the slight trough between the Thames and the Medway, and is bounded on the south by a wooded range of London Clay hills, and on the

north by the marshes of the Thames, interrupted by the rise of the Chalk at Cliffe.

The new railway leaves the North Kent line some three miles E. of Gravesend, passes at first over a small flat of river-gravel, and then crosses the Canal, where a good deal of peat, with remains of trees, was found, to an island in the marsh on the west of Higham. Here there is a small cutting in brown London Clay. The line then runs over the marshes for more than a mile, until near Cliffe Rectory, just to the south of which is a long and deep cutting excavated in Thanet Sand, and very wet at the bottom. In the middle of this sand are seen here and there signs of slight erosion, or of gentle current bedding, a most unusual thing in this division of the Lower London Tertiaries. The next cutting eastward is small, and seemed to be in the same sand; but we did not stop to examine it.

The chief cutting is through the hill eastward of Cooling Court, and it shows the whole of the beds from the bottom of the London Clay to the top of the Thanet Sand. Owing to the westerly slope of the line, and to the slight easterly dip, the lowest beds are cut into only towards the west, whilst at the east the shelly clay of the Woolwich Beds sinks to the level of the rails. The beds are as follows, and they occur in even succession without any erosions :—

Brown clay, apparently London Clay, but without any sign of the usual pebbly basement-bed; up to about 8 feet.

Oldhaven Beds.
- Fine buff slightly false-bedded sand, with masses of fossils in places (*Cardium*, *Pectunculus*, *Natica*, *Corbula*, *Lamna* teeth and vertebræ, and pieces of carapaces of Turtle) (?); up to 8 or 10 feet.
- Small flint-pebbles in sand, generally about 6 inches; but in one part nearly 3 feet.

Woolwich Beds.
- Light-coloured sand, with incipient tubular concretions, (?) about 7 feet.
- Shelly clay (*Cyrena*), about 3 feet.
- Sharp grey sand, with traces of peaty matter in the upper part; many feet, but the whole thickness not seen at one place.
- Thin layer of very small flint pebbles in pale greenish sand.

Fine soft Thanet Sand; a few feet.

At the eastern end of the cutting there is a mass of brown

brick-earth, probably the result of the wash of the hill. Many fossils were collected from the Oldhaven sand; but it is to be feared that few were successfully brought home, on account of their perishable nature.

A small unfinished cutting, a little further east, is in sand, which probably forms part of the bed beneath the shelly clay.

After a meat-tea we strolled into the combined cutting and pit at Higham Station, and noticed the junction of the Thanet Beds and the Chalk, thus continuing and completing the downward procession of the Tertiary Series. A persistent layer of flint through the midst of the chalk was also observed.

EXCURSION TO TOTTERNHOE, KENSWORTH, AND LUTON.

SATURDAY, 25TH JUNE, 1881.

Directors:—PROFESSOR MORRIS, M.A., F.G.S., JAMES SANDERS, ESQ., AND JOHN HOPKINSON, ESQ, F.L.S., F.G.S.

(*Report by* MR. HOPKINSON.)

The Dunstable Downs form the most elevated tract of country north of London, within the area of the Chalk formation, in the trough of which lies the London Tertiary Basin, their highest point, Kensworth Hill, being at least 800 feet above sea-level. The Chalk here forms two escarpments, but the higher beds of the Upper Chalk are not represented, the main escarpment exposing the outcrop of the Lower Chalk and the lower beds of the Upper Chalk, and the secondary escarpment the lower beds of the Lower Chalk and the upper portion of the Chalk Marl, with the Totternhoe Stone forming its highest bed.

To gain a knowledge of the physical features of the Dunstable Downs and surrounding country, and to examine the Totternhoe Stone, which only occurs on the north-west outcrop of the Chalk Marl, the members of the Geologists' Association, the Hertfordshire Natural History Society, and the Luton Natural History Society assembled at Stanbridgeford Station at about half-past 11, and at once proceeded, some in carriages and some on foot, to the Totternhoe quarries, where a good section of the Totternhoe Stone is exposed.

Mr. Saunders here said that this bed usually occurred in two seams, each about three feet thick, and consisted of a compact arenaceous limestone, which, in working, separated into massive blocks. Its sandy nature suggested a break in the continuity of the physical conditions which accompanied the deposition of the other beds of the Chalk formation which were almost purely calcareous. The Totternhoe Stone played an important part in modifying the physical features of the district. At its junction with the overlying bed many springs took their rise, the long-continued action of which had been the primary agent in excavating those coombs or valleys which were so characteristic of chalk escarpments. Of these escarpments examples might be seen at Ivinghoe, Barton, Ravensbury Castle, and Pegsdon Barns. Of the rarer fossils found in this bed, Mr. Saunders mentioned that he had discovered part of the jaw, with teeth, of *Ichthyosaurus campylodon*, and a crustacean, *Palæga Carteri*, the first of its kind which exhibited the caudal appendages by which Dr. Henry Woodward was enabled to determine the affinities of the species.

Rain had fallen heavily in the morning, and now it again descended, rendering fossil-collecting not such a pleasant occupation as it would otherwise have been. A good many fossils were, however, found, including *Rhynchonella plicatula* and *R. octoplicata*, *Terebratulæ*, *Inocerami*, &c., teeth of *Ptychodus*, and a fragment of a large dorsal spine of a sauroid fish, the only important find. Some nodules of chert were also obtained.

The party then walked across the fields to Totternhoe Knoll, on the summit of which Professor Morris gave an address on the physiography of the district, explaining how some of the Chalk beds were more or less indurated than others, and how the varying degree of hardness and softness rendered them more or less liable to the effects of sub-aërial denudation, thus determining the physical features of the country. The Chalk, he said, once extended over a wide area in a north-westerly direction, and had been subsequently removed by denudation. Chalk escarpments, as thus left, which formed such a prominent feature in English scenery, had been inferred to be sea-cliffs, but that could not be the case, for the sea cuts indiscriminately through all classes of rocks, and would have left water-worn flints, pebbles, and sand at the base of the escarpment instead of the unrolled and unbroken flints here seen. After alluding in succession to the most interesting points con-

nected with the physical character and extent of the contiguous underlying strata, the Gault, Lower Greensand, and Purbeck beds, Professor Morris referred more particularly to the influence of the range of the Lower Greensand on the physical features and water-supply of the neighbourhood, illustrating his remarks with a geological map which, however, was partially sheltered from observation and rain by an umbrella. Before he could finish, heavy rain and a gale of wind drove the party down the hill, and into the village inn below for shelter and refreshment.

The rain soon ceasing, Totternhoe was left for Kensworth Hill. At the foot of the hill a spring was examined, and a discussion ensued as to the stratum which retained and threw out the water on the hill-side, for its position appeared to be above the line of junction of the Chalk Marl (or its highest bed the Totternhoe Stone), with the more porous chalk overlying it. The water from the spring had carved out for itself a valley in the chalk, affording an example of the mode of formation of the coombs which are so characteristic of chalk escarpments.

A steep climb soon brought the party to the summit of Kensworth Hill. Here a splendid view of the surrounding country was obtained. On the south the ground was seen to slope gently in the direction of Kensworth, while to the north was the steep escarpment which had just been climbed, with the lesser, Lower Chalk escarpment of Totternhoe Knoll and the Maiden's Bower below it, and here and there an outlier of the Chalk might be seen forming a slight elevation on the gault plain beyond. The height of this hill is generally given on maps of the district, &c., as 904ft. above the sea-level, but Mr. Hopkinson stated that, from aneroid measurements he had made from beach-marks on the Dunstable road, he believed the summit was about 810ft above Ordnance-datum.

The route now lay by Kensworth Green, through Kensworth churchyard, and across the St. Albans and Dunstable road, to Caddington. Here the carriages were waiting to convey the party to Farley Hill, Luton, where Mr. Henry Brown, President of the Luton Natural History Society, had kindly offered to provide tea at his residence, "Highfields."

After a substantial meal had been partaken of, in a marquee erected for the purpose, Mr. Hudleston, as President of the Geologists' Association, proposed a vote of thanks to Mr. and Mrs. Brown, which was seconded by Mr. Hopkinson, as Secretary of the

Hertfordshire Natural History Society, and heartily carried. Professor P. Martin Duncan, F.R.S., then expressed the thanks of the party to the Directors, specially mentioning the wide extent of knowledge of the local geology of England possessed by Prof. Morris.

Before separating, the members of the three Societies had an opportunity of inspecting a fine collection of local fossils made by Mr. Saunders, and some artistically-executed diagrams, illustrating the geology of the district, prepared by Mr. A. Ewen.

(Postponed Paper.)

On Coniferæ.

By J. Starkie Gardner, F.G.S.

(*Read May 6th*, 1881.)

Viewed apart from what geology has made known of their history, the Gymnosperms or Gymnogens appear to form the simplest and a rather abnormal group of Dicotyledons (presenting some affinities with Monocotyledons and certain resemblances to ferns). When, however, their past history is taken into account, they are seen to so far exceed in antiquity the rest of Dicotyledons and the Monocotyledons, and to be of such importance in the study of the evolution of the vegetable kingdom as to demand a separate division in any system that claims to be a natural one.

The Gymnosperms, indeed, present in many respects an intermediate group between the highest form of organization and the lowest. Their chief distinction lies in the fact that the naked ovule is fertilised directly by the pollen without the intervention of stigma, style or ovary. Lindley* considered them, in this respect, analogous to reptiles in the animal kingdom, their ova being fertilised by direct contact with the male principle. Darwin † contrasted the method of reproduction among Gymnosperms with the admirably ingenious contrivances by which many other plants are fertilised by insect agency. "Can we consider," he says, "as equally perfect the elaboration by our fir trees of dense clouds of pollen, in order

* "Veg. Kingdom," p. 221.
† "Origin of Species," 3rd edit., p. 223.

that a few granules may be wafted by a chance breeze on to the ovules?" Their woody tissue, although exogenous, has a peculiar and easily recognisable structure, marked by disks, and their spiral vessels are stated to be less perfectly formed than in most other flowering plants. These somewhat anomalous characters have led to their being very variously placed in botanical systems, as may be seen in the following examples:—

Linnæus classified Cycas with the Palmæ, and the Coniferæ between the Grasses and Amentaceæ. Lindley's system, 1833, is the earliest in which the Gymnosperms occur as a primary division equal in value to the Exogens and Endogens—his "Gymnospermæ" including Cycadeæ, Coniferæ, Taxineæ, and Equisetaceæ. In the most recent classification, the Index Plantarum of Hooker, the Gymnospermæ form the last, or the 114th to 116th orders of the Dicotyledones.

The imperfectly studied and scanty relics of former forests which have been found scattered, with wide intervals, through stratified rocks, have scarcely yet rendered it possible to trace the lines through which the evolution of any of the groups of the existing plant world has taken place. Still, the known antiquity of completely differentiated Acrogens and Gymnosperms is such that we can only suppose the common ancestors of the spore-producing Lycopod and seed-producing Gymnosperm to be locked up in the form of graphite and other carbons in the estimated 70,000 feet of sedimentary strata comprised between the Laurentian and Devonian formations. No real advance can in fact be made on Adolphe Brongniart's division of the development of the vegetable kingdom into three great periods—that of the Acrogens, of the Gymnosperms, and of the Angiosperms. In the oldest sedimentary rocks, there are, as is well known, no recognisable plant remains. In the sea-deposits of the Silurians, the oldest known impressions of terrestrial plants have been met with, and these most unmistakably belong to true ferns.* In some of the Devonian rocks, wood with the typical coniferous structure abruptly appears, but in other localities wood of the same age occurs with an anomalous structure, seeming to show that the Coniferæ were not then so clearly differentiated as they now are.

In 1831, Witham pointed out that the higher and more com-

* Dr. Hicks has recently obtained some plant remains from the Denbigh Grits of a very anomalous and primitive character.

plex organization of Coniferæ existed in the carboniferous strata of Edinburgh and Newcastle. The example referred to was believed to possess an Araucarian structure, and more recently has been considered to be nearer Pinus. The Gymnosperms of the Carboniferous, however, are remarkable for the complete absence of any true cones, and the presence of fruits, such as Trigonocarpus and Nœggerathia, acknowledged by both Hooker and Saporta to be allied to Ginkgo. If the frequent reference of the earliest known Conifers to such genera as Araucaria and Ginkgo should stand the test of time, it would be a matter of considerable interest to find that the forms, which at the present day still closely approach in their foliage the club-mosses and ferns, are the older types. Ginkgo, in its mode of seeding, still presents, according to Saporta and Marion, a nearer approach to Cryptogams than any other existing Dicotyledon.

From the base of the Permian the Gymnosperms are more defined. Voltzia (supposed by Brongniart to possess near affinities to Araucaria and Cunninghamia) is thought by Saporta to belong to the Taxodiæ, the many distinct types of foliage included in the genus perhaps accounting for the divergent views. The widely-spread Walchia and Ullmannia have been generally supposed to be Araucarian, although the latter has also been placed in the Cupressineæ. The Cycadeæ were largely developed throughout the Permian, and until the close of the Jurassic.

In the Trias, besides some doubtful Cupressineæ, two prevailing types occur—a form of Voltzia, thought by Schimper to be related to the existing Cryptomeria, and Albertia related to Dammara. Coniferous wood is abundant in the Lias, both the Araucarian and Pine structure having been recognised, and we meet with the suggestive names, Widdringtonites and Thuites. Four species of the latter are known from the Stonesfield slate besides Araucaria, and Solenhofen has yielded Pinus, Araucaria, and Arthrotaxites. The Secondary period has, in fact, frequently been described as the age of Gymnosperms. The Jurassic appears to have been the most essentially so, for they then formed almost the entire forest vegetation. Schimper enumerates more than 60 species of Cycadeæ; the Cupressineæ and Taxodieæ are undoubtedly represented, and distinct cones of Araucaria and Pinus have been met with in several localities both in England and abroad. *Ginkgo digitata* is indis-

tinguishable from the existing Ginkgo, and the Pachyphyllum from the middle estuarine series of Yorkshire bears a most striking resemblance to *Araucaria Cunninghami*, but differs in possessing smaller ovate and persistent cones, not dissimilar in appearance to miniature cones of the Araucaria.

The Wealden flora is almost a continuation of that of the Jurassic. The British Cretaceous Flora, described by Carruthers, is nearly entirely Coniferous, Cedrus having been met with in the Lower Greensand at Maidstone and Shanklin, several species of Sequoia and of Pinus, and foliage and amber in the Gault, and a Sequoia cone from Blackdown. The Cretaceous Flora of Hainault is also, like that of Folkestone, entirely Coniferous, and is described by Coemans as containing connecting links between the groups of Abies and Cedrus, Strobus and Pinaster, Cembra and Strobus. Germany seems to have yielded cones of Dammara and Araucaria. Cedar cones have also been found in the Wealden of the Ardennes and cedar and pine cones in the Lower Cretaceous of Havre. The Cretaceous rocks of Aix-la-Chapelle contain Glyptostrobus, Sequoia, Araucaria and allies of Libocedrus and Thuya. In the Arctic Kome bed Heer claims to have true pines, and Tsuga, also Abies and Pinus from Atane, so that, even in Cretaceous times, forests of needle-leaved Coniferæ must have characterised Northern latitudes. The needles of *Pinus Credneri* are described as lying in thousands on some of the slabs. Pinus and Sequoia are found in the newer American Cretaceous of Dakota.

In the Tertiaries the Gymnosperms are quite subordinate to the higher Phanerogams, yet in 1878 Lesquereux estimated that no less than 225 species were known from them.

Of the three orders of Gymnosperms, two are distinctly recognised in British Tertiary Rocks. Sir Joseph Hooker has recently expressed the opinion that "of all the orders of fossil plants of the formations referred to (the Cretaceous and Tertiary strata of North America), the Gymnosperms alone have, as a rule, yielded much trustworthy information; and this is due to their texture, to the peculiar character of their vegetative and reproductive organs, to the frequent adhesion of these to the branchlets, to their gregarious habits, to their wide distribution, and to their close affinity with existing species." The similarity in the foliage of Conifers belonging to widely different genera, however, renders deter-

minations, when based only upon fragments of foliage, of little value.

Coniferæ.—The Coniferæ form by far the most important order of Gymnosperms. They are trees or shrubs with branched, resinous trunks, and abound in the temperate regions of both hemispheres. The name is derived from the strobilus or cone on which the greater proportion of them produce their seeds. This is a fruit spike, more or less elongated, and covered with scales or bracts formed of metamorphosed leaves or branchlets, each scale with usually two seeds at its base, enveloped in a hard coriaceous integument and often winged. The scales are sometimes united, as in the Cypress, to form a rounded mass; or become fleshy, as in the Juniper, where they unite to form a globular fruit like a berry. In the Taxeæ and Podocarpeæ the fruit is solitary and terminal, the external succulent covering being formed of modified bracts surrounding a naked seed. This is the only order—except parts of stems of Ephedrus, a genus of Gnetaceæ—definitely known to occur in our Tertiaries.

Although Gymnosperms no longer play the chief part in forest vegetation,* yet the Coniferæ form a conspicuous feature in the physical geography of the earth. They are remarkable not only for majesty and symmetric grace, but for the stupendous bulk, compared to that of leafy trees, that individuals attain. Pines, firs, cedars and larches form enormous forests in the Northern Hemisphere, where the winter is most severe, supplying food and shelter to many animals which could not otherwise maintain their existence. Araucarias, Podocarps, Dammaras and Dacryds, conifers of a very different aspect, occupy corresponding tracts in the Southern Hemisphere. No genus inhabits the plains of the Tropics, the present habitats of the conifers being essentially in the temperate and sub-Arctic zones. In the Northern regions of Europe, Asia and America, its members outnumber the broad-leaved trees by ten to one, and even on the Pacific slopes extensive tracts are densely wooded by them, with scarcely any admixture of deciduous trees. The Pine barrens in North America stretch over [illegible] to [illegible] miles, while the belt of conifers is almost continuous in the Old World from Scandinavia to the Eastern Coast of Asia.

The enormous areas now occupied by the Coniferæ would hardly

* Buckland, "Bridgewater Treatise," vol. i., p. [illegible], says they form but [illegible] of the vegetation.

lead to the supposition that any great diminution is taking place in their numbers through natural causes; yet instances of their areas of growth and the number of their individuals becoming sensibly smaller are not unfrequent. *Taxus baccata* appears to have everywhere diminished, for in Cæsar's time history leads us to suppose that it formed extensive woods. *Abies pectinata*, formerly abundant in England, N.E. France and Denmark, has long since become extinct in these places, through some unknown and remote cause. *Abies excelsa* is no longer an English tree, though no reason for this can be assigned. It is limited at the North Cape, according to De Candolle, by want of heat, not excessive cold, though winter cold excludes it from Russia and Sweden and want of heat from Norway. In Spain *Abies Pinsapo* becomes rarer year by year.* In Switzerland the records of the diminution in the areas of the coniferous forests are abundant, and the destruction cannot in very many cases have been due to the agency of man. The limit at which conifers cease to grow there has become materially reduced, foron the upper confines of Alpine forests there is everywhere evidence that they are retreating towards the valleys. The pines are not dwarfed towards their superior limits, and do not creep as bushes to the verge of the snow-level as on other mountain ranges, and towards the poles; but isolated and grand old pines, larches, or firs, stand out beyond the rest, as if their exceptional vigour had enabled them to survive the adverse influences to which the weaker trees had succumbed. On the Splugen, Juliers and Simplon, large roots are found where now scarcely even bushes will grow, and, on the Valais Alps, remains of large trees far above the limits of forest vegetation. The names of certain heights and valleys now almost bare of trees indicate their former wooded nature. In Madeira the Juniper and the Yew, the only indigenous conifers, are practically extinct in the wild state. It is difficult to estimate the former extent occupied by the Cedars of Lebanon,† but they are

* All the forests in Spain seem diminishing, and but seven per cent. of the country is now forest, perhaps accounting, as in Syria, for its present sterility. France has 17 per cent., Austria 30 per cent., Prussia 23½ per cent., and Bavaria 32 per cent. of forest.

† From the frequent mention of them in the Book of Kings, the Psalms, &c., they must have been very extensively used in the building of Jerusalem. The fourscore thousand hewers and 3,000 overlookers kept in the Lebanon by Solomon during the building of the Temple and the House of Lebanon, were, of course, chiefly employed in hewing stone.

now confined to a few scattered groups on the mountains of Syria, their destruction having probably materially modified the climate.

In Siberia, on the other hand, the Coniferæ seem to be gaining ground, and creeping up towards the North Pole, for Middendorf notices the young look presented by the Larch forests of Northern Siberia, which he considered to be barely half-a-century old.

Besides being the hardiest, the Coniferæ certainly form the most gigantic trees on earth. The loftiest of them is barely exceeded even in mere height by the slender, quick-growing Eucalyptus, but as solid masses of timber, they individually far surpass every other forest tree.

The colossal size of the mammoth trees of California has long excited wonder, yet these " Big trees " are rivalled by many of the Pines of Western America, the sizes of which, huge as they appeared, seem to have been actually understated in text books.

Thus, the Douglas Pine, *Abies Douglasii*, which forms the chief part of the gloomy forests of the Rocky Mountain Valleys, is stated by Douglas and by Gordon, to be from 150 feet to 200 feet in height, with a circumference of from 20 feet to 50 feet, by Herschell and by Humboldt 245 feet high and 57½ girth. Yet there is a section in the Kew Museum, exhibited in 1862, from a tree measuring 309 feet in height and 185 feet to the first branch. The spar in the pleasure grounds at Kew is from this species, and though but 159 feet high, is seen from a distance to far overtop the trees in the grounds. *Abies Menziesii*, or the tide-land spruce, is said by Gordon to attain the height of 100 feet, but a section exhibited in the Philadelphia Exhibition, taken 98 feet from the ground, and measuring 6 feet 10 inches diameter, was stated to have been cut from a tree 318 feet high with a diameter of 16 feet at the butt.* *Picea grandis*, or the yellow fir, said by Gordon to reach 200 feet, and by Herschell 224 feet, far exceeds these dimensions, for sections were exhibited by the State of Oregon, cut from a tree 321 feet in height and 15¾ feet diameter at the butt, 6 feet 10½ inches exclusive of bark at 130 feet, and 5 feet 10 inches at 200 feet from the ground. *Picea nobilis* is fully as gigantic. *Pinus Lambertiana*, another giant, has its height stated by Gordon at 200 feet, Emer-

* " Report Phil. Int. Exhibition, 1876," Vol. iii., p. 500. These extreme heights seem rarely to be attained

son 230 feet, Herschell 235 feet, and Lindley expresses surprise at the stupendous height of 230 feet, yet Newberry states it at 300 feet. The height of *Pinus strobus*, or the Weymouth Pine, is variously given; by Gordon as 100 feet to 150 feet, Emerson 130 feet to 140 feet, the Kew Guide 120 feet to 160 feet, and by Dwight in the report on the trees and shrubs of Massachusetts at from 250 feet to 264 feet. A plank of *Thuja gigantea* (said by Gordon to be from 50 to 150 feet high) was exhibited at Philadelphia from a tree 325 feet in height. On the other hand, the heights ascribed to the Wellingtonia, *Sequoia gigantea*, have been doubtless exaggerated. Herschel calls them "the loftiest and grandest of trees, said to attain the almost fabulous height of 400 or even 500 feet, with a diameter of 40 or 50 feet near the ground."* In the "Treasury of Botany," the tallest tree in the mammoth grove is stated at 327 feet in height and 90 feet in girth, which is near the maximum height assigned to them by Hooker, 325 feet. The largest tree on record however, is broken at 300 feet from the ground, and measured at the break 18 feet, and at 3 feet from the ground 87 feet in girth. Its stump tapered regularly, and the tree is calculated to have been 450 feet high. *Sequoia sempervirens* reaches 300 feet, according to the "Treasury of Botany," and according to Hooker 270 feet, with a girth of 55 feet at 6 feet from the ground.

Although America and especially the Sierra Nevada furnishes the most gigantic coniferous forest trees to be found on the globe —yet the conifers of many other regions rival them in size. In the Himalayas *Pinus excelsa* reaches 200 feet, and bears cones 1 to 2 feet long; the stately *Cedrus deodara* 200 feet and 36 feet in girth; *Abies Smithiana* 170 feet, *Picea Pindrow* 150, and the gloomy *Cupressus torulosa* 150 feet and 16 feet in girth at 5 feet from the ground.

In the Southern Hemisphere many of the New Zealand Podocarps exceed 200 feet in height. The *Araucaria imbricata* of Chili reaches 260 feet, *A. Cookii* 200 feet, *A. excelsa* or the Norfolk Island pine 224 feet, *A. Bidwilli* and *A. Cunninghami* reach 150 feet.†

Contrasted with these is *Dacrydium laxifolium*, the most diminutive pine known, fruiting specimens being, according to Kirk,

* "Physical Geography," p. 311,

† "Jury Reports, Sydney Exhibition, 1870," p. 643.

sometimes only two inches high, while the average height is only 6 to 10 inches.

The ages attained by some of the Coniferæ are scarcely less extraordinary than their colossal bulk. The greatest longevity assigned to any tree is perhaps credited to the celebrated Taxodium of Chapultypec in Mexico, 117 feet in circumference, which was thought by De Candolle to exceed in age the Baobab of Senegal inferred to be 5150 years old. Goeppert states that Taxodium distichum has been ascertained by its annular rings to live 2000 years* The mammoth tree has been estimated to live 4000 years in California. De Candolle quotes a number of instances of longevity in the yew, and Endlicher considers one in Derbyshire to be 2096, and the one at Grasford,† in North Wales, 1400 years old. The pines, cypress, firs, larches and cedars, are credited with ages of two, three, and even 500 years. A Picea, 200 feet in height, is mentioned by Goeppert, as ascertained by its annular rings, to be 460 years old, and a Larix of 120 feet to be 576 years old. The Scotch *Pinus sylvestris* is said to require 200 years to mature its timber to perfection.

The literature, even of the fossil Coniferæ, is naturally large, for petrified wood early attracted attention. Brongniart, however, only found himself able to enumerate Pinus and Abies as actually defined genera. A complete list of works of reference on the subject is found in "Goeppert's Monograph of Fossil Coniferæ," Leyden, 1850. For a critical list of later works upon the subject, Schimper's "Paléontologie Végétale," 1874, should be consulted, and notices of works that have appeared subsequently to this date are to be found in the "Geological Record."

I will now give some of the more interesting details of the families of Gymnosperms, especially from a Geological point of view.

Cycadaceæ.

These are Gymnosperms, with simple continuous stem, strongly marked with lozenge-shaped scars, and parallel-veined hard pin-

* The rings of growth in Eucalyptus have been ascertained to be biennial. The Cedars planted in England show symptoms of decay, as in Richmond Park, as if their full age, in this climate at least, were already reached.

† Diameter according to Endlicher 50 feet, and Selby only 29 feet.

nate leaves. The wood is soft and pith-like, but with the characteristic Gymnospermous structure. They are generally low shrubs, but occasionally reach a height of 30 feet, and may be described as possessing the fruit of conifers and the general aspect of palms. They are natives of Intertropical America, Asia, Australia, and the Cape. The order includes only two families, Cycadeæ and Zamiæ, but fully 100 species are known. They abounded in England during the Jurassic times, and excellent illustrations of them are to be seen in Buckland's "Bridgwater Treatise," the "Transactions of the Geological Society," 2nd series, Vol. iv., and in Lindley and Hutton's "Fossil Flora." They have also been met with in the Jurassic of Spitzbergen, and in great quantity in the Cretaceous of Kome in Greenland. They become very rare in the newer Cretaceous of Atane, and seem, in Europe at least, to have died out before the Tertiary period, for none of the "Zamites" of this age yet published can be considered satisfactory.

Coniferæ.

The first tribe, the Cupressineæ, are large, very resinous trees, or shrubs, with small scale-like leaves, comprising the hardiest in existence. The cones are small and globular, and composed of 4 to 8 or rarely 10 pedate persistent scales, except in Juniperus, in which they coalesce into a fleshy galbulus or berry.

Their origin is traced back to the Permian, if Ulmannia is really Cupressineous, and they became during the late Jurassic and Wealden, the preponderating tribe. Some of the forms are of interest, among them being Widdringtonites, Echinostrobus, Thuyites, Thujopsis, but they are all more or less imperfectly known, and the abundance of the tribe is partly inferred from the prevalence of wood called Cupressinoxylon.

The genus *Callitris* is represented at Sheppey by fruits belonging to the Tetraclinus or 4-valved fruit section, now confined to North Africa; and by even more distinct fruits of the Hexaclinus division (Frenela) now entirely confined to Australia and New Caledonia. While these latter (specimens of which I have recently obtained from Sheppey through Mr. Shrubsole), though almost identical with an existing species, were not described by Bowerbank, the supposed 3 and 5-valved Cupressineous fruits in

Bowerbank's work cannot be united to any known genera. The living fruits are remarkably persistent on the trees, remaining attached for many years, with the valves gaping widely open, and their presence among the Sheppey fruits, even rare as it is, is singular. The total absence of the elsewhere widely-spread Eocene Thuja and Libocedrus, whose cones, shed in thousands, float easily, and are almost imperishable, is significant of the climate at this period.

Callitris Brongniarti, belonging to the quadrivalved division, is one of the most distinct Eocene Conifers of Europe, and has been met with in most of the Eocene floras of France and Austria, though not in England. It is beyond doubt a close ally of the existing species, for well-preserved fruits have been found attached to the foliage. The presence of species belonging to the now purely Ethiopian, Pachylepis section (Widdringtonia) is far more doubtful, and in Greenland, where it has been determined on a single small mutilated twig, the evidence is absolutely trivial.

The 2nd genus, *Actinostrobus*, is represented by a single cone from Sagor, and the 3rd, *Fitzroya*, has not been found fossil.

Libocedrus, the 4th genus, has small scale-like foliage, and ovate cones of 4 to 6 leathery, very unequal valves, and cannot easily be mistaken. The species, which occasionally form very large trees, inhabit temperate regions, even reaching the snow-level, and are widely scattered. *L. salicornioides*, another thoroughly well-determined European Tertiary fossil, seems rather confined to the Oligocene or Lower Miocene of Central Europe, and has been met with neither in Italy nor England. A Spitzbergen species, of Eocene age, is compared to the existing Chilian species. I have now to add a very distinct and beautiful form from the Lower Eocene of Bromley, which will be described in the pages of the Palæontographical Society.

The 5th genus, *Thuja*, has similar foliage, with oblong, coriaceous, persistent, 6-10 valved cones, and also contains gigantic species. With one exception it is now confined to the Palæarctic and Neartic regions. No remains are known in Europe below the Armissan beds (Tongrian), where they are rare, but in the late Miocenes of Italy, Amber beds of Prussia, etc., they are very plentiful. Heer recognizes an Arctic species from some very small terminal buds.

The stately *Cupressus* forming the 6th genus is scarcely

known fossil, except possibly from two German Miocene localities and from Antrim (?).

The large genus *Juniperus*, which has such an immense range at the present day, including the hardiest shrubs on earth, is only known fossil from the Eocene of Aix, Häring and the Prussian Amber bed. It is one of the few European Eocene conifers that survive, the existing and allied *J. excelsa* still inhabiting almost the same spots.

Of the Cupressineæ, we thus possess two well marked and distinct types of *Callitris* at Sheppey, about which we can speak with the utmost certainty—the one being at present confined to North Africa and the other to Australia. While the Australian type has never yet been met with except at Sheppey, the Palæarctic type had a considerable range in Europe during the remainder of the Eocene period. *Libocedrus* is present in our earliest Eocenes, and re-appeared of a different species, over a great part of Europe, in the Miocene; yet it is everywhere absent in the warmer Eocene period in Europe, and also in the Miocenes of Italy. *Thuja* first appeared during the Miocene in Europe, and *Juniper*, rare in the Eocene, has persisted through the Miocene to the present day. Other supposed Tertiary Cupressineæ I consider unreliable, but the ranges of those briefly mentioned above are highly suggestive and the determinations trustworthy.

The second tribe Taxodieæ comprises the gigantic Sequoiæ, the swamp cypress of America and Japan and other important genera, all trees of large size with small ovate cones, and either spiral or distichous foliage. The tribe is not traced to times more remote than the Jurassic, although *Ullmannia* of the Permian has been thought to be an ancestral form. None of the existing genera appear until the age of the Gault, when *Sequoia*, and, in the later cretaceous, *Glyptostrobus*, are seen. On the other hand, some very remarkable extinct genera as *Inolepis* and *Cyparissideum* from the Greenland Lower Cretaceous are placed in it. Although the existing genera cannot yet claim a very remote antiquity, they all consist of remarkably few species, with restricted ranges. From their former abundance and wider distribution, some at least seem to be verging on extinction.

Of the five genera, *Cryptomeria*, now confined to Japan; *Arthrotaxus*, confined to Van Diemen's Land; *Cephalotaxus*,

confined to China and Japan, have never been described as fossil; although *Taxites Olriki* from the Greenland Eocene should probably be transferred to the latter.

The genus *Taxodium* has now but three species—the gigantic swamp cypress, and its near ally the Mexican cypress of North America, and the small *Glyptostrobus* of Japan. The cones are small, ligneous, and so persistent, that in formations where closely similar foliage abounds without being associated with them, we are justified in inferring that the foliage belongs to some other genus. The section *Glyptostrobus* first appears in the Cretaceous of Greenland, and is said to occur in the Eocene and Miocene of Europe, though a good deal of the foliage referred to it more probably belongs to other genera. Its presence is well ascertained, however, from many of the later Tertiaries, such as those of the Baltic, Bilin, Radaboj, Turin, Eubœa, etc. *Taxodium* itself does not appear in Europe until the Miocene, and the Eocene of Atanekerdluk, Spitzbergen and Alaska. It seems, however, to have descended from the Arctic regions, reaching as far as Colorado and Marseilles during the Miocene. The finest specimens are figured in Heer's "Baltic Miocene Flora." Nearly all the fossils have been referred to a single species closely allied to the existing *T. distichum*.

The *Sequoiæ* are monœcious, and have obtusely ovate, ligneous, and terminal cones one to two inches in length, which are persistent on the branchlets. The scales are spirally disposed, 16 to 35 in number, wedge-shaped, with a transversely oblong nail-like head, wrinkled and depressed, and mucronate in the centre, sharing to some extent the ornamentation which seems characteristic of the tribe. The foliage is distichous and yew-like in *S. sempervirens*, and spiral and imbricated in *S. gigantea*, but both occasionally foliate in the opposite way.

The earliest known Sequoias are Cretaceous, and were described by Carruthers from the Blackdown Beds and the Gault. Schimper speculates upon its derivation from some much older Araucarian form, and its foliage in the Cretaceous period certainly approaches more nearly to the Araucarian type than does that of either of the existing species. Saporta regards the Chalk period as the age of Sequoias, and our principal knowledge of these is derived from Heer's "Flora Fossilis Arctica." At this period the distichous and the imbricated types of foliage, characteristic at the present day

of distinct species, were not differentiated. Heer unfortunately failed to appreciate this fact, and in endeavouring to distinguish them has made many unnecessary species, and caused very considerable confusion.

The chief and most interesting characteristics, besides the union of the two varieties of foliage, is that the distichous arrangement was produced in the cretaceous species, if the plates are correctly drawn, by the shortening almost to abortion of the upper and under leaves, and not by their being narrowed at the base and twisted, as at present, towards the sides of the branchlets.

The Arctic Tertiaries have yielded no foliage of the *S. gigantea* type, except that referred to *S. Couttsiæ*, but which I prefer to distinguish, for reasons fully set forth elsewhere, as *S. Whymperi*. The *S. sempervirens* type was then most abundant, *S. Langsdorfii* being in fact the prevailing fossil in Greenland, scarcely any stone with leaf impressions being without some remains of it. The branchlets are generally simple and single, rarely forking, and would thus seem to have had a short season of growth and to have been quickly shed, an adaptation probably to the long Arctic winter. *S. Langsdorfii* again appears in the Miocene of the Baltic, in the Aquitanian and Mayencian stages in Switzerland, Germany, Austria and France, and finally reached Italy in the Upper Miocene period. The branchlets from more southern deposits become more compound. The Eocenes of France have yielded two species, one very distinctly and the other to a less degree dimorphic, that is uniting the two types of foliage in one plant; and an extremely dimorphic form, *S. Hardtii*, is abundant at Steiermark and Häring in Austria. Even *S. Langsdorfii* has more decidedly imbricated fruit-bearing branchlets than *S. sempervirens*, whilst *S. Whymperi* seems certainly to have been dimorphic, and also to have descended south towards the Miocene period. Another Eocene form, no less dimorphic and belonging to the same group, is *S. brevifolia*, Lesq., for a specimen of which, from Florissant, U.S.A., I am indebted to Mr. Pattison.

The purely imbricated type, which is more prevalent in the Cretaceous, becomes rarer in the Tertiaries. I have, after very mature deliberation and for reasons set forth under *Araucaria*, determined to consider the so-called *S. Sternbergi* of Bournemouth an Araucaria. In Iceland an unusually large foliaged Sequoia is met with, which is very distinct from the typical *S. Sternbergi* form. It

re-appears in the Superga of Turin, in both cases being associated with cones, at Senegal (*Pinites cryptomerioides*, Mass.) and in the Great Lignitic of America (*S. acuminata*, Lesq.). *S. Couttsiæ*, from the unusual grace and delicacy of its foliage, forms an extreme contrast to the last species, and is one of the few Eocene Sequoiæ not subject to dimorphism.

From the fossil Sequoiæ we learn that the differentiation of the foliage of the present species is not a character of more than specific value, and if we examine the two species which now exist by the light of the past, we notice that they are less distinct in type than they outwardly appear; for *S. sempervirens* preserves the spiral scale-like leaves for a short distance at the base of each branchlet, and *S. gigantea* sometimes assumes the distichous arrangement. In addition to this the foliage of the former is not in two rows as it is in Taxodium, being spirally arranged round the stem; but the flat and expanded leaflets have a powerful tendency to crowd into two lateral rows, so that the surface of each may be as fully exposed as possible to sun and moisture. The leaflets, to accomplish this, take a half twist near their base, and then diverge upward or downward towards the sides of the branchlet, an additional row frequently lying centrally along the branch. The closely allied *Glyptostrobus*, it is interesting to notice, possesses dimorphic foliage to an even greater degree now than formerly.

The genus *Sequoia* seems to have become well nigh exterminated during the Glacial Epoch, and has been most strangely preserved in the two isolated spots, where the recent species occur, perhaps outside its original range, where the moderating influence of the Pacific enabled it to survive, or occupy at a remote period the lofty spurs of mountains, when their valleys were filled with glaciers. Fixed in exceptionally favourable stations, and with congenial soil, the existing species may have slowly adapted themselves to a temperature far more genial than that supported by their polar ancestors. In estimating the minimum temperature that the latter could have supported, we may therefore be entirely misled by relying exclusively on the data furnished by the existing species. In adapting themselves to always increasingly favourable conditions, may they not have acquired that stupendous habit of growth which makes them the giants of vegetation?

With regard to the supposed British Eocene Sequoiæ, *S.*

Sternbergi, *S. Richardsoni*, *S. Langsdorfii*, *S. du Noyeri*, etc., I see at present no evidence whatever for retaining any hitherto described British Tertiary fossil in the genus except *S. Couttsiæ*.

The 3rd tribe, TAXEÆ, are also generally large trees, some even gigantic, and occur in the milder climates of both hemispheres. They are distinguished from all other conifers, except the *Podocarpeæ*, by their fruit not being collected in cones, for each ovule grows singly, and is protected by a fleshy disk, or forms a drupe. Lindley considered them to be lower in the scale than the cone-forming conifers. Their leaves are narrow and veinless, or expanded with the forked venation of ferns. There are six genera existing, and many extinct, for the tribe is traced back through Ginkgo to the Permian, and, possibly to the Carboniferous. No existing genus of Taxad is, however, known, of greater age than cretaceous, except Ginkgo.

The 4th tribe, PODOCARPEÆ, consists, with the exception of two small genera, each with but a single species, of the genus *Podocarpus* alone. The species of Podocarps, are, according to Gordon, 59 in number, and vary from mere shrubs to colossal trees, inhabiting the temperate zones of Asia, Africa, Australia, and America, but principally of the southern hemisphere. The fruit is solitary and drupaceous or nut-like, and contains a seed with a hard crustaceous shell. The leaves are linear, and arranged in two rows, or overlapping, and in a few species present a dicotyledonous venation.

I can find no record of any Podocarp of older date than Eocene, but in the middle Eocenes of South Germany, and Austria, England, and France the unmistakable leaflets of Podocarps, belonging to the group of *P. andina* or of *P. chilensis*, abound. In addition to this large-leaved form, however, I believe that some of the taxiform Coniferæ of Alum Bay and Bournemouth are true Podocarps. The drupaceous character of the fruit renders it extremely difficult of identification, but in one instance, at Alum Bay, I have found it with the characteristic foot stalk, and attached to a taxiform branchlet; and at Bournemouth I have also found podocarp-like fruits. At Sheppey again I have collected singularly well-preserved fruits with the exact form and peculiarly wrinkled skin of *P. elata* of Queensland. Apart from the fruit,

however, the foliage bears a remarkable resemblance to that of *P. tenuifolia*, or *P. cupressina*, and being dimorphic, could only be referred either to this, or *Glyptostrobus*, or to *Sequoia*. The absence of cones, which are persistent and always found in deposits where either of the latter are abundant, sufficiently precludes their reference to these.

The 5th tribe, the ARAUCARIEÆ, contains four genera—*Cunnimghamia*, *Agathis*, or *Dammara*, *Araucaria*, and *Sciadopitys*.

The first genus, *Cunninghamia*, has been stated by Sternberg, Heer, and Ettingshausen to be represented in Cretaceous formations, and a small fragment of foliage from the Miocene, is also called *Cunninghamites*, by Ettingshausen. It is unknown in the Eocene, and is now restricted to a single species, a native of China and Japan.

Agathis contains 8-10 species, inhabitants, for the most part, of the Malayan Isles, Fiji, New Caledonia, New Zealand, and Australia. *Agathis australis*, the Kauri pine, is the most celebrated and beautiful of the New Zealand trees, reaching 180ft. in height. (Several of the other species are very imperfectly known.) Like *Araucaria*, there is supposed evidence of the presence of allies of *Agathis* in the Carboniferous period, though it is not until the Cretaceous that any forms are sufficiently defined to be named even Dammarites. No Eocene species are yet known, though a leaf and a scale from Bournemouth strongly resemble *A. robusta*.

The earliest traces of distinctly coniferous wood known were once believed to belong exclusively to the Araucarian type. The genus was unmistakably present in Europe during the Jurassic period, since which time it appears to have steadily declined. Thiselton Dyer has stated that it became extinct north of the equator from the Oolitic age, and Schimper that it disappeared from Europe with the Tertiaries. I believe, however, that I have convincing proof that a tree, indistinguishable from *Araucaria Cunninghami* of Australia, flourished upon the shores of our British Eocene River, exactly as it does now on the shores of the Brisbane River, 10,000 miles away. Not only must it have been a characteristic tree in England, but one widely spread over Europe, for the greater part of the foliage, miscalled *Sequoia Sternbergi*, is, as it was originally described to be, Araucarian. Cones of Araucaria are shaken to pieces by the wind, the scales having only the

slightest attachment to their axis when ripe. These scales are winged, and contain the seed, and fall long before the branchlets are shed, and would therefore necessarily be floated far away, and deposited separately from the foliage. Only in cases where some violence has operated, could a young cone with the sap still flowing, and in a condition to hold together, become detached, and two specimens of such immature cones have been actually found with the foliage, though they are persistently called *Sequoia* by Heer. It may seem a small matter to insist strongly upon, but if the so-called science of palæo-botany is ever to be of any practical use, such glaring errors must be rectified. Mistakes such as that which persistently transfers one of our chief types from its perfectly natural surroundings of Smilaceæ, Aroids, and fan-palms to another type that only exists on a lofty mountain, which it occupies to the exclusion of almost all other trees and shrubs, must bring, and has brought, the study of fossil plants into contempt. So blindly, however, do foreign palæo-botanists follow Heer, that, without the slightest valid grounds, four species of Sequoia are introduced upon paper into our British Eocene flora, which never existed there in fact. Having undertaken the work without any idea of the loose manner in which Tertiary fossil plant determinations had usually been made, I now frequently find myself confronted with the ungrateful task of exposing the worthlessness of work which has hitherto been accepted by a large section of geologists, at least, as scientific. The study is beset by difficulties so grave, that except in rare instances, it is impossible to determine *with absolute certainty* what any of the mutilated plant remains really are. Yet in no other branch of science is there, I believe, anything to be met with comparable to the assurance, positivism and infallibility with which decipherers and species makers in this branch have published their opinions.

The 6th tribe, the ABIETINEÆ, is by far the most extensive tribe, includes the genera *Pinus*, *Cedrus*, *Picea*, *Tsuga*, *Pseudotsuga*, *Abies*, and *Larix*. That is to say, it comprises the whole of the pines, firs, cedars, and larches, in fact, with few exceptions, all the coniferous trees characteristic of our own and European countries. I have not hitherto come across any statement that cones, referable to this tribe, have been found of older date than the Jurassic.

PINES appear in the Jurassic as Pinites. True *Pinus* is met with

in the Neocomian, and has continued through every subsequent formation of the northern hemisphere to the present time, more than 100 species being described.

Cedrus appear for the first time in the Neocomian. The present Lebanon, Atlas, and Himalayan cedars are believed by some botanists to be mere varieties, and a 4th and new species or variety has been discovered in Cyprus since its annexation.

It does not appear that *Picea*, *Tsuga*, or *Pseudotsuga* have been found fossil, except the former, somewhat doubtfully, in the Gault of La Louvière, and in more recent deposits.

Abies appear in the later Cretaceous, and persists to the present day.

Larix comprises eight to eleven species at the present day, but cannot be traced back beyond the Miocene.

In our British Eocenes, the cones of true Pines have been met with from the Thanet Beds, Woolwich and Reading Series, London Clay, Bracklesham and Bembridge Series, though no pine foliage has, I believe, ever been found associated with the abundant plant remains of our Eocene deposits. This is not the least remarkable of the problems connected with the distribution of our Eocene Coniferæ.

ORDINARY MEETING.

JULY 1st, 1881.

W. H. HUDLESTON, ESQ., M.A., F.G.S., President, in the chair.

The list of donations to the Library since the last meeting was read, and the thanks of the Association returned to the Donors.

The following were elected Members :—E. J. Turnbull, Esq. ; H. Virtue Tebbs, Esq. ; A. R. Rayden, Esq. ; C. W. Blackman, Esq. ; Dr. W. Summerhayes ; Rev. E. D. Wells, B.A. ; and Miss Agnes Swain.

The following Communication was then made :—

ON THE GEOLOGY OF THE NEIGHBOURHOOD OF KESWICK (WITH REFERENCE TO THE LONG EXCURSION).

BY W. H. HUDLESTON, M.A., F.G.S., PRESIDENT.

Introductory.—It has occurred to me that, instead of reading a paper on the geology of this interesting district, I might offer for your consideration a few descriptive notes, and point out some of the more salient features which have already occupied the attention of so many authors. Poets and physicists have been alike attracted by the charms of the English Lakes, and Sedgwick himself was one of the earliest to investigate the geology of the region. To say nothing of his numerous contributions to the volumes of the Geological Society on this subject, his letters in Wordsworth's Guide* are still of the deepest interest to the student. In later times the works of Phillips, Harkness, Nicholson, and Ward, have largely contributed to elucidate the somewhat complex and difficult geology of the country, and the latter devoted himself to the geology of the neighbourhood of Keswick, which more especially concerns us this evening.

Perhaps at this stage a brief outline of the physical geography of the Lake Country might enable you better to comprehend what I am about to say. For this purpose I would direct your attention to the Ordnance Survey Map in shaded contours now on the screen. The Lake District, as most of you are aware, is comprised within a somewhat insulated circular area of mountains occupying the south of Cumberland, together with the adjacent parts of

* 5th ed., Kendal, 1859.

North Lancashire and Westmoreland. The mountains are unusually lofty for England, and contain by far the highest summits to be found out of Wales and Scotland. A watershed running nearly east and west, and almost on the parallel of St. Bee's Head, divides the country pretty equally, the waters to the north flowing into the Solway, those to the south in the direction of Morecambe Bay. The northern area, with which we are most concerned this evening, is sub-divided in the first instance, by the Helvellyn range, so that the waters flow into the basins of the Eden and Derwent respectively. The Keswick district lies wholly within the latter basin.

This almost circular group of mountains consists of three grand divisions of Cambro-Silurian rocks, the lowest and oldest being the SKIDDAW SLATES. The central region is occupied by the VOLCANIC SERIES, and the highest beds are the SILURIANS, that have the Coniston Limestone for their base. Without prejudice, and as a matter of convenience, they might be termed the Lower, Middle, and Upper Silurians respectively. With these are associated certain granites, "syenites," &c., and the entire group is set in a low frame-work of Carboniferous and Permian rocks. Three mountain masses are conspicuous upon the map : two of these, viz., the Scafell mass and the Helvellyn mass are situated close to the great east and west watershed previously mentioned. Though not actually coincident with the main watershed, these masses, contained entirely within the Volcanic Series and its associated rocks, attract a large rainfall, and must have exercised considerable influence during the period of Glaciation. The mountains associated with Skiddaw form the third mass.

From south by west to north the lowlands of Lancashire and Cumberland intervene between the Lake District and the sea, but on the east a belt of mountainous country, constituting a prolongation of the main watershed, connects it with the great Pennine Chain of the North of England, formed entirely of Carboniferous rocks. It is across this part of the watershed, in the neighbourhood of Shap, that the London and North Western Railway passes from the basin of the Lune into that of the Eden at the moderate elevation of about 800 feet. The line thus skirts the eastern margin of the Lake Country, which presents a strange jumble of peaks as viewed from the windows of the railway carriage. The summit-cutting discloses slaty rock, dipping at a high angle and in

contact with a mass of trap, unconformably overlaid by a red conglomerate now regarded as forming the base of the Carboniferous Limestone. The moor is strewn with masses of the celebrated porphyritic granite of Shap, now so largely worked for economic purposes in the neighbourhood of Wasdale, a little to the west of the line. Boulders of this easily identified granite are scattered over the north and east of Yorkshire, and there is a large one at Seamer station close to Scarborough.

The run down to Penrith, the Redhill of the North—a fall of about 500ft. in 13 miles—is not long in being accomplished. This portion of the line lies wholly within Carboniferous or Permian rocks. The view across the broad valley of the Eden, bounded on the east by the huge mass of Crossfell—the highest portion of the Pennine Chain—is very fine. This valley is in the main due to the great Pennine fault. The central portions consist chiefly of Permian sandstones, some of which are rather sterile. Yet a tourist, in summer, would hardly agree with the old saying that "Westmoreland hath much *Eden* but little *Paradise*."

From the platform of the Penrith station Helvellyn and the mountains about Ullswater are distinctly visible. To Keswick by road the distance is 18 miles W.S.W. The railway, owing to the difficulty of gradients, has to adopt a more circuitous route, passing chiefly through the Carboniferous rocks which form the setting of the Lake District proper. Some of the cuttings show sections of boulder clay resting on the Limestone. Not far from Penruddock the summit level is reached, and an excellent view of the mountains in the neighbourhood of Keswick is obtained. But there are two masses in the immediate foreground which will attract our attention. That to the left is Mell Fell, which just appears on the rough enlargement of quarter sheet 101 S.E. of the Geological Survey now placed upon the screen. Though only 1,760ft. above the level of the sea, its rounded outline at once attracts attention, whilst to the geologist its peculiar situation and internal composition are both highly suggestive. The hill is part of a remnant of the Basement Conglomerate of the Carboniferous Limestone (Upper Old Red of some), resting quite unconformably partly upon Skiddaw Slates, partly upon the Volcanic Series. This tells a story of two great denudations at different epochs. First of the enormous destruction of the Cambro-Silurian rocks, secondly of an immense removal of post-Silurian deposits, ere this hill could

have been fashioned into its present shape. But a still more remarkable fact remains to be told. The materials composing this hill do not consist of trap, or ash, or of Skiddaw Slate, such as occur in the immediate district, but for the most part of grit or micaceous sandstone like some of the Upper Silurians in the southern part of the Lake Country. The bearing of all this on the physical history of the region may again be mentioned.

But we must remember that we are on the summit of the Penrith and Keswick Railway, and that the really noble mountain mass in front is the eastern side of Saddleback, 2,847ft., (composed entirely of Skiddaw Slate), which here shows the saddle to great advantage. I have generally considered that this shape was due to a synclinal on the mountain top, the left wing of the synclinal dipping to the north-west, whilst the right wing dipped at a less

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Note in Explanation of the Accompanying Sketch Map.

Based on the Map in the Survey Memoir, 101, *S.E.*

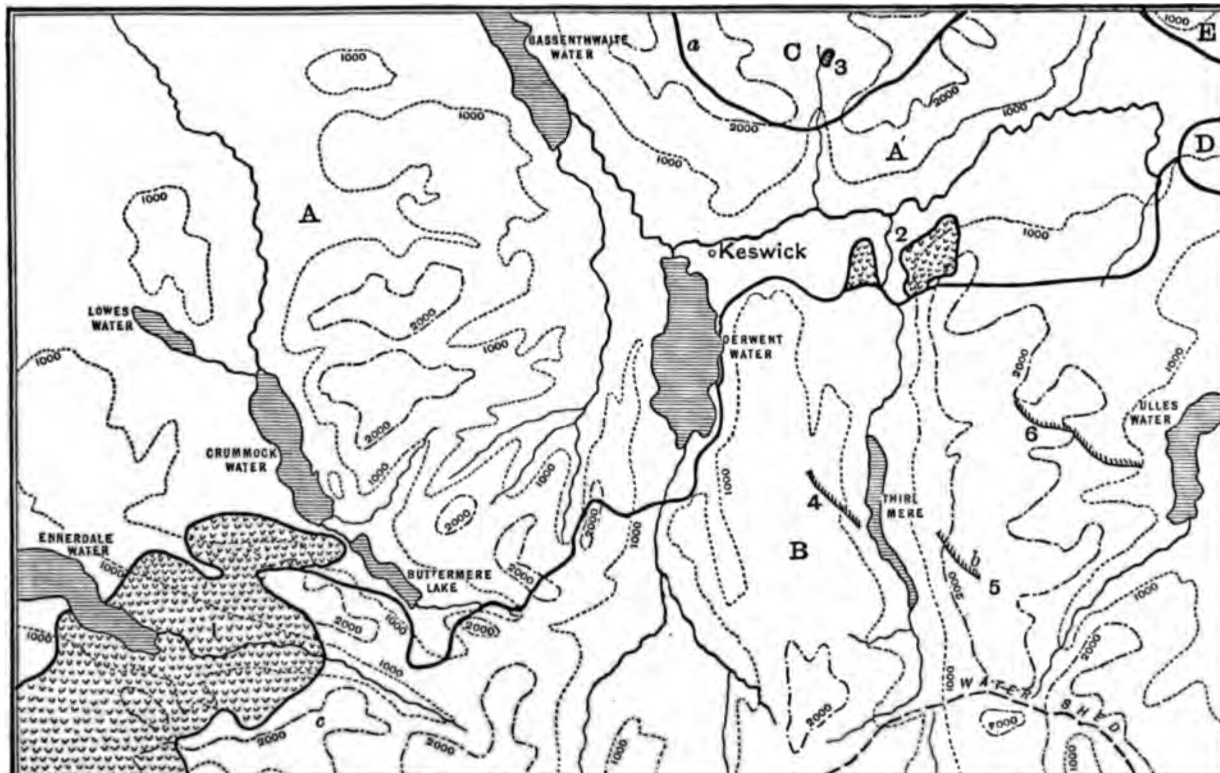
A. Skiddaw Slates, west of Derwent.
A'. Skiddaw Slates, east of Derwent.
B. Volcanic Series of the Central region.
C. Metamorphic Series of Skiddaw Forest.
D. Basement Conglomerate of the Carboniferous System (Mell Fell).
E. Volcanic Series of the northern region; a small portion only appears in this quarter sheet. It comprises the remarkable porphyrite of Eycott Hill.

N.B.—The strong dark lines represent geological boundary lines.

1. Buttermere and Ennerdale "Syenite."
2. St. John's Quartz-felsite.
3. Granite of Sinen Gill.
4. Armboth Dyke—quartz-porphyry.
5. and 6. Similar dykes in the Helvellyn range.
   a. Skiddaw, 3054 feet.
   b. Helvellyn, 3118 feet.
   c. Pillar of Ennerdale, 2927 feet.

N.B.—These three represent the culminating points of the three great mountainous masses, mentioned in the introduction, within the area of the map. Only a small portion of the south-western mass, which culminates in Scafell, 3210 feet, and of which the ridge of Pillar forms one of the radii, is seen in this quartersheet. This mass was the great nursery of the glaciers which descended into Borrowdale.

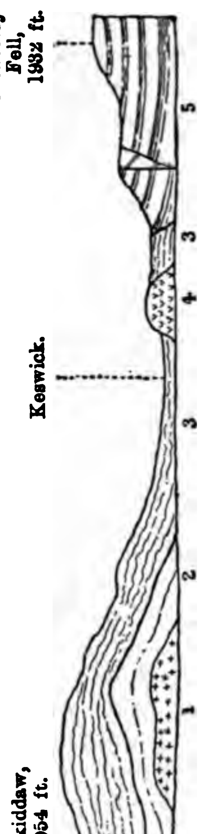
FIG. 1.—SKETCH MAP OF THE COUNTRY ROUND KESWICK.



REFERENCE. ------------ 1,000 ft. Contour —·—·—·—·—2,000 ft. Contour. v v v v v v Syenite, Quartz-felsite, Granite, &c.

angle in the opposite direction.* The cleavage on the contrary, where developed, dips at a high angle to the south-east. This mountain is also known as Blencathra, supposed by some to mean "The Peak of Demons," and has always been regarded as one of the most effective in the Lake District, but it looks so different from different points of view that a stranger would hardly recognize it.

Fig 2.—Diagrammatic Section through Keswick, Modified after Clifton Ward.



1. Skiddaw Granite. 2. Spotted and Chiastolite Schists. 3. Skiddaw Slates. 4. Castlehead eruptive trap (doleritic). 5. Volcanic Series.

The railway, in its descent, now enters a wide tract of glacial clays, resting on Skiddaw Slates, and finally reaches the valley of the River Greta, which cuts deeply into the latter formation. Thence it emerges into the Vale of Keswick, locally known as the Vale of Crosthwaite.

The advantages to a geologist of making Keswick head quarters are very considerable. The town is situated near the most beautiful of all the English Lakes, and not far from the great faulted junction of the Skiddaw Slates with the Volcanic Series, which may be studied with great facility at several points on the eastern side of Derwentwater. Many of the most interesting exposures of igneous, granitic, and metamorphic rocks are within easy reach by road or rail. Added to these natural advantages, there is a good local museum, well furnished with model, maps, sections, and specimens illustrative of local geology.

* In the Survey Map the general dips hereabouts are given at about 50 N.W., and, although the strata are represented as rolling, no opposite dip is shown in figures.

Having now, as I hope, adduced a few reasons for advocating the selection of Keswick as the centre for our Midsummer Excursion, I must say something about the several formations and physical history of the neighbourhood.

Skiddaw Slates.—This series is the lowest and oldest in the district. Keswick itself stands upon it. The whole of the great mountain mass to the north, including Skiddaw and Saddleback, is composed of it. The beds for the most part consist of glossy black or dark-grey rocks, flaky, and in parts well cleaved, but almost always useless for economic purposes, though the group contains many mineral lodes or veins, some of which have formerly been worked to a profit. Interstratified with these softish shivery slates are inconstant gritty bands, which are sometimes micaceous slates, flaggy and current marked, and sometimes more massive. The entire group has undergone a considerable amount of alteration from pressure, and shrinkage, and is often much crumpled and cleaved, to say nothing of the more decided metamorphic action to which, as we shall see presently, a portion of these rocks have been subjected.

The thickness of these old mudstones has been variously estimated. Professor Harkness thought that 7,000ft. was sufficient, but Mr. Clifton Ward considered that 10,000, or even 12,000ft. was not too great an estimate. When we consider that no true base has been seen,* and furthermore bear in mind the tremendous amount of folding, crushing, and crumpling that has taken place over regions where the beds are most difficult to trace the accuracy of these estimates may be liable to considerable doubt.

This great thickness of rock is, on the whole, but poorly fossiliferous; in fact, for years scarce a trace of an organism was found. As recently as 1845 Sedgwick wrote a paper† in which he made a comparison between the series of rocks in Wales and in Cumberland. He then considered that there was no exact representative of the Skiddaw Slates in North Wales. After a physical description of the group, he goes on to say that, although containing in one or two places a quantity of carbonaceous matter, the rocks do not effervesce with acids, and no fossils have as yet been obtained from them. He further ventured to predict that, if fossils were discovered, they would belong to some of the oldest Protozoic types of our island. The prevalent idea 35 years ago, certainly

* The lowest beds are supposed to be in the mountain Grassmoor.

† Q. J. G. S., vol. i., p. 449.

was that nothing would be found, and, as far as I can discover, previous to the publication of Harkness' paper* in 1862, only two species of graptolites from these beds were known to the bulk of geologists.

The paper in question was the first of a series in which the late Prof. Harkness, occasionally assisted by Prof. Nicholson, threw a flood of light upon the history of the Skiddaw Slates. The author admits that Joseph Graham (since deceased) was the first person to recognize the fossiliferous localities in the neighbourhood of Keswick, and I have myself often conversed with Graham, who was a particularly pleasant and unassuming man, upon the subject. His chief hunting grounds were at Outerside and Barff, where some flaggy strata lying above certain cleaved rocks, yielded several species of Graptolites. At Outerside these flaggy beds dip S.S.E. 30°, whilst the flaggy beds at Barff dip N.W. 30°. A bagful of fossils,† according to Harkness, might be found at the latter place.

Since those days Mr. Kinsey Dover, one of the directors of the Excursion, has made a splendid collection, which you will have an opportunity of inspecting.

The *Volcanic Series* forms the middle of the three great divisions of the Lake District rocks. It is by far the most important, comprising the grandest and most varied scenery; and is on the whole, despite of its not containing a single fossil, the most interesting ground for the majority of geologists. The old name of "Green Slates and Porphyries," so much used by Sedgwick, was changed by Nicholson in 1872 to that of the Volcanic Series of Borrowdale, and this title has been adopted by Mr. Ward and the Survey, as the former especially objected to the use ot the term "porphyry" in a substantive sense.

Most stratigraphists have concluded that the Volcanic Series really does overlie, with possibly no great amount of unconformity, the Skiddaw group. But the evidence is not forthcoming in the neighbourhood of Keswick, since the junction between the two series is faulted all along the sinuous line. The question of position is an important one, and I shall recur to it again when we

* Q. J. G. S., vol. xix., p. 113.

† Such is not the case at present, the "screes" having been too well picked over. Randel Crag, near the summit of Skiddaw, has been a favourite locality with Mr. Dover.

consider the stratigraphy of the district. At present we are concerned only with the character of the rocks forming this particular group, and for the study of this the vicinity of Keswick affords ample opportunities. The following may be accepted as a rough classification of the lower division of the Volcanic Series in descending order :—

1. Lavas (contemporaneous) and ash of Bleaberry Fell.
2. Breccia and bedded ash—largely developed.
3. Lavas (contemporaneous) and ash of the Falcon Crag series.
4. Basal beds containing the purple breccia.

On referring to the Circular, you will find that, after inspecting the collection in the Town Hall, we are to examine Mr. Ward's typical section of lavas and ashes of the Falcon Crag Series. These constitute the lowest beds of the group accessible in this quarter, and are very well seen in the precipices on the eastern side of Derwentwater, where for many hundred yards the fault may almost be said to coincide with the wall of rock forming the eastern margin of the Lake, whose bed lies wholly within the Skiddaw Slate area. The lowest beds visible, those in fact which arise straight out of the lake, are of a somewhat indefinite character, but we shall note on the level of the Borrowdale road, and for a considerable distance above, a remarkable mass of purple breccia, forming great groups of jointed blocks, and standing out from the rest, as Clifton Ward observes, like fragments of Cyclopean masonry. This is part of the coarse ash underlying the alternations of lava and finer ash which succeed.*

Falcon Crag itself towers up on the east, being one of the salients of the steep escarpment, which, availing ourselves of the Catgill ravine, it will be our duty to climb. The height is not far short of 1,000 feet above the lake (238 feet above sea level), and within that space are five distinct beds of lava separated by a corresponding number of ashy beds; but above the great basal breccia the lava beds vastly preponderate in volume. As we ascend the ravine we shall probably be able to make out the several beds. The tops and bottoms of these lava beds are often very slaggy and vesicular, containing much quartz, calcite, and green earth as amygdaloid.

The lava which composes the main mass of Falcon Crag (No. 4 of Ward's section) is the most important of these several beds;

* "Survey Memoir," p. 18.

it has a maximum thickness of 150 feet, and its sheets frequently exhibit a curved tabular structure, which is very curious; it is considerably jointed, and often breaks with a sort of conchoidal fracture. In hand specimens the rock is of a dull bluish aphanitic appearance with considerable specific gravity, and seems almost homogeneous. It may be taken as a type of the closer grained and more basic lavas of the district, which are allied to "whin," *i.e.*, basalt. No analysis has been given of this particular lava, but microscopic examination shows that it is truly crystalline. Like other similar lavas it displays a network of acicular felspar prisms which are often much masked by the quantity of "chloritic" mineral diffused through the mass. Augite in recognisable form is not abundant or well preserved; magnetite, in small and regularly distributed specks, is plentiful and characteristic. In the Lodore trap, which also belongs to the lower series of lavas, the microcrystalline character is still more pronounced. Aphanitic diabase is probably the more correct petrological term for such rocks.

The beds of ash in this series are not very thick, and in hand specimens it is not always easy to say which is ash and which is lava. But for the most part there is not much difficulty in determining the point when sections are placed under the microscope, as the fragmental appearance and the absence of the network of felspar prisms is usually a good indication. Thus a slice of ash, *h* of Ward's section, is distinctly fragmental, with crystals and pieces of a decomposed felspar, and the "chloritized" remains of what was probably augite, the whole held together by a fine felspathic dust. This is to a great extent the character of the less obscure varieties of "ash;" and occasionally, as in ash *i*, of this series, regular lines of bedding seem to imply that it may have been deposited in water. Moreover, in this case the felspar crystals and also many of the augite fragments have their longer axes in one direction, and some greenish yellow fragments (? epidotized augite) are distinctly rounded.

Although there is no particular difficulty with regard to the ash of the Falcon Crag Series, the subject of volcanic ash as a deposit in the older rocks is none the less obscure in general.* In

* "The so-termed fluxional character is by no means an uncommon feature in this class of sedimentary rock, built up out of the materials of the old igneous rocks, where the ground mass may be observed in wavy lines round the uncrushed fragments and crystals."—Prof. N. S. Maskelyne.

some cases the coarsely fragmental character of the ash is obvious enough on a weathered surface, whilst the interior shows hardly a trace of its clastic origin. Weathering is often one of the best ways for bringing to light the original structure of a rock, which has been obscured by partial metamorphism. On the whole we shall not come across much altered ash in this particular group—a fortunate circumstance, since ash of any kind is bad enough, but a fine altered ash, such as the hornstone-like rocks which used to be called "hard blue flinty," is rather a discouraging subject for beginners. There is plenty of this in the upper parts of the series.

We must now, following Mr. Ward, shift the line of section a little in order to take in a fresh series of lavas and ashes, best observed under Bleaberry Fell, a mountain mass of the second order (1,932 feet), of which Falcon Crag may be regarded as one of the buttresses. Here there is a complete series of lava flows above those previously mentioned with hardly any intervening ash. This part of the hill (Brown Knotts) has the appearance of a flight of steps, especially as seen from the other side of the lake, justifying the old term trap (? staircase), from the Swedish "trappa," a stair. The base of this series is rather more crystalline in hand specimens, and looks less aphanitic than those "whins" previously described, and is, according to Ward's description, somewhat microporphyritic.

I will now pass on to describe the very interesting lava, which forms the highest bed of the series (No. 12 of the typical section) above Brown Knotts, and which extends to the mural precipice of Iron Crag in Shoulthwaite, whence the specimen on the table was obtained. This rock, in its present condition, might be described as a felsitic diabase with a microporphyritic structure. In thin sections we fail to observe many of the acicular felspar prisms which make up so much of the Falcon Crag and Lodore traps. On the contrary, we observe a greyish felsitic-looking ground mass interspersed with "chloritic" matter in which are distributed porphyritically many crystals of felspar considerably altered, and also some very distinct crystals of partially "chloritized" augite in groups. Much of the felspar is probably oligoclase. The magnetite is chiefly developed in connection with the augite crystals, and occurs in irregular blotches with ragged edges.

Clifton Ward has given us an analysis of this rock and also of the one at the base of the group (No. 6). The one contains

rather more alkali, more alumina, and less oxide of iron, lime, and magnesia, and slightly less silica than the other. The mean composition, omitting small fractions, is as follows :—

Silica			60·11
Alumina			16·17
Ferric Oxide	1·33	7·00	14·56
Ferrous Oxide	5·67		
Lime	5·71	7·56	
Magnesia	1·85		
Potash	3·03		5·90
Soda	2·87		
Carbonic Acid			1·60
Loss on ignition			·79
Accessories			·77
			99·90

It will be seen at once that this is not the composition of true dolerite, where the percentage of silica should not exceed 51. A felstone, or acidic lava, on the other hand, should contain not less than 70 per cent. of silica. This intermediate class of rock largely prevails throughout the district. Speaking generally, the protoxide bases are chiefly lime and iron, with a moderate amount of alkali, the excess of potash in these two cases being, perhaps, exceptional. A very general feature is the small amount of magnesia in these lavas, and this deficiency is characteristic of nearly all the rocks in the Lake Country, so that magnesian minerals (*i.e.*, minerals containing a large proportion of magnesia, such as olivine, serpentine, hornblende, magnesian chlorites, &c.) are not likely to be met with in any quantity. The green colour of these old diabases is often due to the products of alteration of augite, which may sometimes be regarded as "chloritic," sometimes "epidotic." Most of the Volcanic Series show effervescence with acids indicating the presence of calcite and other carbonates, resulting in many cases from the lime both of the augite and of the felspar. The epidote which occurs in veins is one of the minerals which has resulted from this decomposition.

The ash of the district is, on the whole, more acidic than the lavas ; often containing nearly 70 per cent. silica. It may be that the felspathic portions of the ejectamenta being lighter would be carried to a greater distance, as suggested by Mr. Ward; but there may have been other causes, such as the ready removal of

basic matter by solvents before the porous material was pressed and consolidated into rock. Moreover, the bulk of the higher beds consist of ash, according to the mapping of Mr. Ward, and this material may have proceeded, in the first instance, from sources which have not yet been recognised.

Erupted and Metamorphic Rocks.—These rocks occur in connection with one or other of the two great groups just mentioned, and frequently along their line of junction. Under this head are included igneous bosses and dykes, and also the Felsites, Syenites, and finally the Granites. The undoubtedly metamorphic rocks of Skiddaw Forest may also be considered here.

The finest eruptive boss in the neighbourhood of Keswick is Castlehead. This mass has penetrated the Skiddaw Slates not far from their junction with the newer series; the slates are very little affected. Friar's Crag, and one or two other intrusive masses about the foot of Derwentwater, on either side, belong to this important eruption, and are probably all connected at no great depth below the present surface. The character of the rock differs considerably according to the position of the specimen. That from Friar's Crag, for instance, is much seamed by calcite, and specimens from the exterior portions of the Castlehead quarry are very fine-grained, and have the iron much peroxidized. The heart of the rock, being the furthest from superficial and contact alteration, is worthy of a closer examination.* Clifton Ward describes it as "an intimate mixture of pale-coloured felspar with augite, and a soft dark-green pseudomorphic mineral, both chlorite and serpentine." The slice now exhibited shows a confused ground mass of interlacing felspar crystals, exceedingly decomposed, but with traces of twinned lamellar structure. With these are associated a few large crystals of a fresh augite, and there is a considerable quantity of greenish and yellowish-green "chloritic" and "serpentinous" matter, the result of the alteration of augite. Magnetite occurs in small amount with some ferric oxide. The accessory minerals in this specimen are rather abundant, and consist of mica, evident from its dichroism, and long needles of apatite. There is also a considerable amount of very clear quartz, which appears to have filled up small cavities in the rock, and is probably of secondary origin. On the whole the mineral constitution of this

* As this mass is supposed by Ward to represent the feed-pipe of the Falcon Crag lavas, it is to be regretted that no analysis has yet been made.

rock is more complex than that of the lavas, and this is perhaps due to its having undergone a greater amount of alteration. In its present condition no term could be more appropriate than that of diabase, but originally it must have been almost an "augite porphyry."

There is another very interesting rock which forms an eruptive boss on the west side of Bassenthwaite, and is easily recognized in boulders, though it is not probable that we shall see any of them. I allude to the mica trap or minette of Sale Fell, which shows, according to Ward, "a pink felspathic base, with an abundant supply of a dark greenish mica."

The Quartz Felsite of St. John's is a quasi-eruptive rock of considerable importance. According to Ward's mapping it occurs in two separate bosses in the Skiddaw Slates, at their junction with the Volcanic Series on either side the opening of the Vale of St. John. The question of origin must stand over for the present; we may perhaps have an opportunity of noting the behaviour of the Slates in contact with it in the great quarry near Threlkeld Station,* whence the specimens now exhibited were obtained. An average specimen of this rock is of a light-greenish colour, and shows in thin sections a felsitic base with a very few double pyramids of quartz and numerous specks of reddish oxide of iron. The usual porphyritic character of felsite is more or less absent, and the few felspar crystals have undergone alteration into a mineral substance of a pale greenish colour. There is much calcite in this specimen, together with stellar groups of crystals which are most probably schorl. The abundance of quartz grains with interstitial felsitic matter is very marked in parts.

The Elvanite of Armboth is another rock allied to the felsitic class, and has pretty nearly the same chemical composition as the quartz felsite. This is undoubtedly transgressive, and is known generally as the Armboth and Helvellyn dyke. We shall probably not see this rock *in situ*, but its boulders are scattered all over the Vale of St. John, whence it has been distributed both east and west throughout the valley drained by the Greta. Perhaps no rock in the Lake District is more beautiful. In a felsitic ground mass are imbedded long crystals of pink orthoclase, with quartz in double pyramids. There is a little mica, probably biotite, and it also contains the same light-green pseudomorphic mineral alluded to in

* The junction observed by the excursion party is a faulted one.

connection with the St. John's quartz felsite. The rock shows the passage between the Felsites and the Granites, but differs from granite in not having the quartz interstitial.

The analysis of this rock may be taken as a type of the felsitic group throughout the district—

			Per cent.
Silica			67·5
Alumina			16·5
Ferric oxide	0·6	2·7	6·5
Ferrous oxide	2·1		
Lime		2·3	
Magnesia		1·5	
Potash		3·0	7·0
Soda		4·0	
Carbonic acid, carb. matter, water, &c.			2·5
			100

It will be perceived that this is by no means a highly acidic rock, the acid element being just sufficient to make normal albite without any residual silica.

From the Felsites we naturally pass to a consideration of the Syenites and Granites.

The Buttermere Syenite occupies a large area, comprising some very interesting spots. Like nearly all these eruptive or quasi-eruptive masses, it occurs at the junction of the Skiddaw Slates with the Volcanic Series. Mr. Ward seems to have thought that this rock was itself the result of extreme alteration of a portion of the Volcanic Series. It is said to be tolerably uniform in character. Specimens from Buttermere consist for the most part of reddish felspars, with some chlorite and hardly any quartz. The chlorite may be the result of the decomposition of hornblende. The analysis shows 71 per cent. of silica, which would leave a balance of 6 per cent. for the formation of quartz, on the supposition that orthoclase felspar alone composed the rest of the rock. Practically there must be rather more free silica.

The great mass of granite about Scafell, generally known as the Wastdale granite, hardly belongs to the neighbourhood of Keswick. A specimen from Lingmell is a regular granite, with much coarse orthoclase and some biotite; the felspar is much decomposed. The Shap granite has already been mentioned.

To the Skiddaw granite we must pay rather more attention, as

we hope to visit one of the exposures, viz., that in Sinen Gill. Moreover we ought to understand something of the Skiddaw granite if we are to grapple with the question of the metamorphism of portions of the Skiddaw Slates.

The rock is a thoroughly normal granite, largely composed of white felspars, but yet with abundance of black muscovite and interstitial quartz. Its analysis shows—

			Per cent.
Silica			75
Alumina			11
Ferrous oxide	1·7		
Lime	1·6	2·7	4·4
Magnesia	1·1		
Potash	4·5		8·5
Soda	4·0		
Accessories			1·1
			100

Here there is 10 per cent. of silica beyond what is necessary to form pure orthoclase, and practically the amount of free silica must be considerably greater, occurring in the form of quartz, which is said to contain numerous liquid cavities. The felspars are prone to kaolinize, and the granite soon breaks up into sand. Still there are portions which have considerable durability, as may be seen from the boulders that have passed through the gorge of the Glenderaterra into the valley of the Greta.

It may be thought that petrology has occupied too much of the evening, but there is one more group of rocks which can on no account be omitted. This includes the Chiastolite Slate, Spotted Schists, and Micaceous Schists of Skiddaw Forest.

In order to observe for ourselves the phenomena of alteration, it will be necessary to penetrate into the wild and lonely glens which lie behind Saddleback. After traversing parts of the mountain composed of ordinary Skiddaw Slate, the first traces of alteration to be noted are a number of faint spots on the cleaved surface of the slates. These become more distinct and larger, till undoubted crystals of Chiastolite occur in prisms and diamond-shaped sections with a dark spot in the centre.

In the second stage of alteration the rock presents a schistose appearance, and "is more massive and less cleaved, the planes of cleavage being replaced by those of an imperfect foliation, which retain, however, the same general strike and dip, though they are

frequently contorted."* This is the Spotted Schist (= the Knotenschiefer of the Germans), the peculiar appearance of which is due, according to Mr. Ward, to the development of rectangular or oblong spots, lying with their longer axes in the plane of foliation, whilst more perfect crystals of Chiastolite and Andalusite† occur in considerable quantity. This rock used to be called Hornblende Slate, and it is from selected varieties that sets of the rock harmonicon have been constructed.

A kind of Mica Schist is the result of the third stage of alteration. The passage takes place through the increase of mica and of quartz, and the disappearance in great part of the andalusite and chiastolite. There is no passage between this bastard mica schist and the granite; the contrast is complete.

We have then, according to the theory usually held, and first, I think, propounded by Sedgwick in 1824, a belief that ordinary Skiddaw Slate has, by a process of metamorphism, developed the phenomena of crystallization above mentioned, the action increasing in intensity as we approach the granitic centres. It is satisfactory to find that, in this case, even Mr. Ward did not contemplate the possibility of the Skiddaw Granite having resulted from the metamorphism of any portion of the overlying series. The chemical evidence against such a notion is too strong to be set aside.‡

* Ward, in Q. J. G. S., vol. xxxii., p. 2.

† *Andalusite*, trimetric, in rhombic prisms which are nearly square. H.7·5 Sp. gr. 3·1—3·3. Composition. $Al_2 O_5 Si$. Silica 37 per cent., alumina 63 per cent. Insoluble in acids.

Chiastolite has the same composition, but with an alteration of structure arising from carbonaceous impurities. These are distributed, in the crystallizing process, along the sides, edges, and diagonals of the crystal. Hardness sometimes as low as 3.—"Dana's Manual," 3rd ed., p. 284.

‡ The following is the composition, roughly stated, of the three varieties of metamorphic rocks deduced from specimens analysed for Mr. Ward. That of Skiddaw granite is given at page 228.

	$Si O_2$	$Al_2 O_3$	Fe O	Ca O	MgO	$K_2 O$	Na_2O	H_2O	Carb. Matter.
Chiastolite Slate...	65·7	14·2	7·3	1·2	2·3	3·3	2·0	1·7	2·0
Spotted Schist ...	54.5	24·0	8·9	1·3	2·4	3·0	2·1	1·3	0·8 Fes_2 1·8
Mica Schist... ...	53·2	24·5	8·6 F_2O_3·25	1·5	1·9	5·0	3·0	1·2	0·7

It is not likely that the granite could have resulted from the meta-

Stratigraphy, Mineral Veins, &c.—The next thing to consider is the arrangement of the rocks previously detailed. In the neighbourhood of Keswick the great feature is the faulted junction of the Skiddaw Slates with the Volcanic Series. This brings me to the question previously mentioned, a question of the utmost importance in the physical history of the district, viz., what was the original relation of the presumed underlying to the newer series?

A marked feature in both the Skiddaw Slates and the Volcanic Series is that neither formation has any visible base in this area. But Mr. Ward tells us that in certain localities, such as Eycott Hill, there does seem to be a sort of interstratification of slate—only a few feet—with massive lavas 3,000ft. thick, some of which are porphyrites of remarkable beauty. The evidence of relative position at Eycott Hill is certainly but slight, as even here the junction with the main mass of the Skiddaw Slates is a faulted one. Elsewhere, as at Shap, the Surveyors believe that they have obtained evidence of conformable sequence.*

Accepting conclusions of which the Keswick district itself affords no proof, we shall have ample opportunities for inspecting the faulted junction along the eastern side of the Derwentwater Valley. Not the least interesting spot for this purpose is at the Falls of Lodore, where the zigzag character of the great compound fault is well seen. (Fig. 3)

Here the low ground at the foot of the falls is composed of Skiddaw Slates, forming a sort of triangle. The Volcanic Series consists of the very peculiar microcrystalline trap, previously mentioned, and bedded ash, which rise up in exquisitely wooded crags cleft by the great chasm of Lodore. Through this the waters of the upland valley of Watendlath tumble in a series of irregular cascades over the huge blocks of volcanic ash which

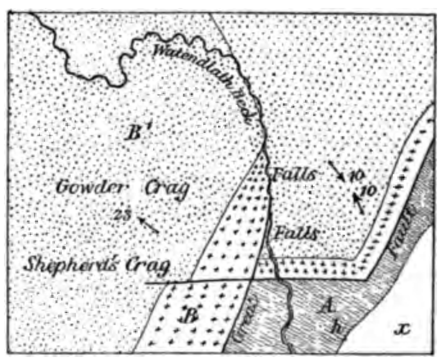
morphism of any of these rocks, which are as much deficient in silica as they are rich in alumina and iron. The granite itself has a fairly normal composition, and must either be intrusive, or the result of the metamorphism of a distinct series of rocks. If, however, these are analyses of typical specimens it is rather singular that the rocks nearest the granite should be those which are the farthest from it in composition. The very considerable difference between the Slates and the Schists is also noteworthy.

The excess of alumina in the Spotted Schist and Mica Schist is what one would expect in rocks containing so much andalusite, which is itself an aluminic subsilicate.

* "Survey Memoir," p. 69.

have fallen from the cliffs above. A subordinate fault runs through the volcanic rocks themselves, whereby, in the lower part of the chasm, the Lodore trap is faulted against the bedded ash. The chasm for a short distance is actually coincident with this fault, which has no doubt determined, in the first instance, the great feature which denudation has in the main accomplished.

FIG. 3.—FALLS OF LODORE.*



[6in. to 1 mile.]

A. Skiddaw Slates.
B. Lodore Trap, } Volcanic Series.
B'. Bedded Ash, &c. }
x. Alluvium bordering the Lake.
h. Hotel.

Another very interesting point in connection with the great boundary fault may be observed a short distance beyond Lodore, viz., in Troutdale, where a projecting tongue of Skiddaw Slates forms the floor of the mountain glen, which thus run up into the very heart of the Volcanic Series.

As regards other faults in the Keswick district they are far too numerous for any special mention. In the Skiddaw Slates the beds are often so muddled up that the faults lack sharpness and precision, and are thus difficult to indicate. In the Volcanic Series, on the other hand, the faults are often very well shown; the beds, owing to their superior hardness, have yielded less to pressure, and instead of being squeezed up preserve their individuality even in dislocation. They are thus thrown into well-marked anticlinals

* From the 6 inch Survey Map.

and synclinals with more or less actual faulting. In this way very obvious stratigraphical features result, like those of the rocks of Naddle Forest, quoted by Mr. Ward, as an instance of a natural geological model.

The general strike throughout the Keswick district is N.E.-S.W., both for the Skiddaw Slates and the Volcanic Series, and the axes of the anticlinal and synclinal folds is mainly in that direction. The prevailing dips are to the S.E. or thereabouts, the principal axis of the region being under Skiddaw Forest.

The cleavage strike of both series has also a N.E. and S.W. direction, with, for the Skiddaw Slates, a dip of about 60° S.E. According to Mr. Ward there are only two instances in these beds of anticlinals in the cleavage. Where cleavage is developed in the Volcanic Series the anticlinals and synclinals are numerous, and the average amount of the dip nearly 70°. Although the finest beds are usually the most cleaved, yet the ashy breccias are also subject to cleavage, as we shall see in the coarse cleaved ash of the Borrowdale slates.

The conclusion is that both groups were cleaved at the same time, and by a pressure acting in the same direction, which pressure also produced very unequal effects as regards contortion, owing to the unequal tension of the beds.

The subject of Mineral Veins, so intimately connected with faulting, deserves a short notice. Ores of lead and copper are the chief products—lead lodes run nearly N.N.W.-S.S.E.; copper lodes about E.-W. The Skiddaw Slates are the most productive in metallic lodes, but very few are now worked. The hill sides of this group are seamed in many places with the marks of old workings, and the Brandelhow lead mine in the S.W. corner of Derwentwater forms a heap of rubbish, which completely disfigures the smooth outlines of that once beautiful bay. The most celebrated mine in the whole district is the copper mine of Goldscope, in Newlands. There is quite a history attached to these mines, which also contain lead. Dalehead, near to Goldscope, is a complete network of mineral veins.

Although the Volcanic Series contains fewer veins, and has been less exploited, the two most important mines in the Lake country are situated in this series, though at some distance from Keswick. The first is the celebrated silver-lead mine of Greenside, on the N.E. of Helvellyn; the other is the old-established Coniston

copper mine, situated in the mountain known as the Old Man of Coniston.*

Geological History, Glaciation.—Having briefly glanced at the composition and arrangement of the rocks in the neighbourhood of Keswick, I must endeavour to say a few words respecting their geological history, reserving any remarks on glaciation to the last. To a certain extent this mode of treatment must of necessity be theoretical; thus far I have only ventured to describe what is, but we must now take into consideration what has been.

The history of the Lake District proper as an area of deposit closes with the Silurian period, at which time, according to the views of Clifton Ward,† the Skiddaw Slates were buried 26,000ft. deep, having over them 12,000ft. of Volcanic Rocks and 14,000ft. of Upper Silurians, commencing with the Coniston Limestone.‡ The mass was raised along the Skiddaw axis, which seems to follow the rule of most of the great earth curves in these latitudes in having a rapid slope to the N.W. and a more gradual one to the S.E.

Whilst this dome or swelling was being gradually elevated the uppermost beds were successively planed off, till at the close of the Old Red period the three great groups of rocks presented themselves pretty much in the same positions they now occupy, the lowest beds having been brought to the surface immediately beneath the Skiddaw axis by the entire removal through marine denudation of the two higher groups. A featureless mass thus presented itself to be fashioned by meteoric agencies. The northern portion of this mass consisted of the Skiddaw Slates, together with those parts of the Volcanic Series which lay to the northward of the geological axis. The central portion consisted of the main mass of the Volcanic Series, whilst in the south, altogether away from the

* Both these mines are supposed to have turned out quite a mint of money in their day, and are amongst the very few still worked. The great rage for limited companies, some few years ago, caused much capital to be sunk in the Lake district. To mineralogists none of the mines of this country are more interesting than those of the Caldbeck Fells, which are situated north of Skiddaw Forest, about the junction of the northern Volcanic Series with the Felsites, "Hypersthenites," &c., so largely developed in that region. A limited company was formed, accordingly, to work these mines, and after something like £60,000 had been spent the bubble burst. At present the valley of Roughtengill presents a melancholy spectacle of expensive ruins. Lead mines in this country have but little chance against the products of Leadville and the "great carbonate camp."—For further information relative to Mines and Mining in the Lake District, see "Essay by J. Postlethwaite." Moxon, printers, Leeds.

† "Geol. Mag.," Feb. 1879, p. 49.

‡ *i.e.*, according to Cumbrian—not according to Welsh classification.

neighbourhood of Keswick, the mass consisted wholly of Upper Silurian rocks. And now I must beg you to recall what was said about Mell Fell in the introductory part of this lecture, and how the composition of that enormous heap of conglomerate and its unconformable position upon the Skiddaw Slates and Volcanic Series shows that this theory of precarboniferous denudation is no vain speculation, but has the best of proofs in its support.

There seems to be a pretty general consensus of opinion that since, if not during, the Carboniferous period the area occupied by the Lake District has been for the most part dry land. It probably formed an island in the Carboniferous sea, and may have been clothed with a carboniferous upland vegetation, of which we know so little. At that early period Skiddaw, Helvellyn, and Scafell had not attained their individual outlines. Moreover the region must have been powerfully affected subsequently by the earth movements, which, during the interval between the palæozoic and mesozoic epochs, gave birth to the Pennine Chain. The faults ranging approximately from north to south would in all probability be produced during that important interval. What other changes were then effected we can only guess at, but we may be sure that throughout the mesozoic and tertiary periods the fashioning process went on. Valleys were deepened, the soft places were found out, and the unequal weathering of the materials gave its impress to the growing scenery. In this way came to pass the striking difference between the country of the Skiddaw Slates and of the Volcanics—a contrast which constitutes one of the especial charms of the vale of Crosthwaite (Keswick), where the soft and flowing outlines of Skiddaw and the Newlands mountains on the north and west is brought face to face with the rugged precipices of the Volcanic Series on the south and east.

The length of time during which there is no evidence of new formations in the Lake District proper seems enormous, but the history of deposits recommences in another form with the glacial period. This has left most unmistakable marks over the whole country, and is far less obscure in its results than in the more low-lying parts of England.

The literature of this subject is very voluminous, but I must content myself with indicating a few of the facts, which are so well brought together by Mr. Ward in his Glacial Sketch map 101 S.E.* The conclusions to be deduced from the distribution of

* "Survey Memoir," plate iv.

boulders may generally be relied upon, and the evidence from ice scratches forms a useful confirmation. As regards these latter Mr. Ward says that in the upper and branching parts of Borrowdale they never ascend beyond 2,000ft., and the direction of the grooving is usually along the valleys. As we come lower down the basin to the Fells on the east side of the main valley there are no scratches above the 1,500ft. contour; and further down still, opposite Derwentwater, 1,200ft. is the limit, the directions mostly ranging from S.-N. to S.S.E.-N.N.W. Close to Keswick itself, viz., on Castlehead, 529ft., the scratches are S.S.E.-N.N.W.

Of actual moraines I need say but little; these generally occur in the upper part of the higher glens. Boulders on the other hand we shall frequently meet with, either in the boulder clay and gravels, or on the hill sides. A knowledge of the several rocks of the district is very useful in this case. The traps and ashes of the Volcanic Series are by far the most numerous, and when in the boulder clay, or on Skiddaw Slates, are easily recognised. Besides these, in the more immediate neighbourhood of Keswick, the most interesting boulder-forming rocks are the Armboth elvanite and the St. John's quartz-felsite. These have come down the valley of the Greta reinforced by the spotted schist and granite of Skiddaw Forest, which have passed through the gorge of the Glenderaterra. Some boulders of the Armboth elvanite are in such a position on the Bleaberry Fell range, at about 1,800ft., as to render it probable that the ice from the Thirlmere Valley did override the watershed hereabouts, but this is quite exceptional.

As a rule each valley system produced its own boulders, and this is so marked a feature in the valley of Crosthwaite that the boulders which have come from the eastern valleys connected with the basin of the Greta still remain on the east side of the vale below Keswick, whilst those on the west belong entirely to the Volcanic Series of Borrowdale itself, which supplied this side of the vale.

Thus it is clear that the motion of the ice was away from the existing watershed; that it was governed and controlled by the existing valley system. The precipitation along this watershed during the Glacial period was perhaps in excess of what it now is; but when we bear in mind that at Seathwaite the annual rain fall is 160 inches,* very little of which falls as snow, we can easily believe that if the temperature were lowered only a very few degrees glaciers would once more fill the valleys that radiate from Scafell.

* Keswick has 60 inches and Ambleside 70 inches.

EXCURSION TO THE LAKE DISTRICT.

MONDAY, JULY 18TH, TO SATURDAY, JULY 23RD.

Directors.—THE PRESIDENT; PROF. J. MORRIS, M.A., F.G.S.; C. E. DE RANCE, ESQ., F.G.S., H.M. Geol. Survey; W. KINSEY DOVER, ESQ., F.G.S.

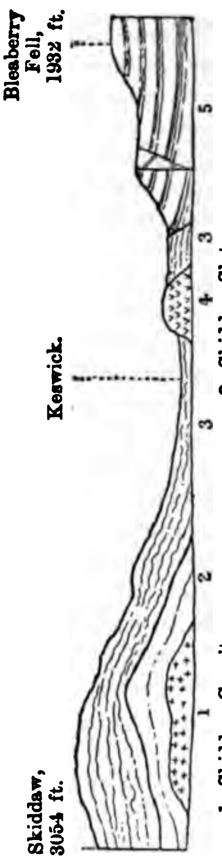
(*Report by* THE DIRECTORS.)

The major part of the body of excursionists arrived at Keswick on Monday evening, and located themselves at the Keswick Hotel. After dinner they proceeded to Friar's Crag and made a cursory inspection of the geological features there, and enjoyed the beautiful prospect of the lake which that point affords. On Tuesday morning the party met at the Museum of Local Natural History to inspect the rock specimens collected mainly by the Rev. J. Clifton Ward. In addition to these, Mr. Christopherson lent a magnificent specimen of pure Borrowdale plumbago. After viewing the model Mr. Hudleston delivered a brief address. He congratulated the members upon their meeting together in such an interesting district, and said it was the first time they had attempted an excursion at such a long distance from London. Keswick was a fortunate centre for them, because of the existence of a society more or less of a kindred nature to their own—the Keswick Literary and Scientific Society. There are few country towns possessing such an excellent museum of local collections, and the circumstance is due to the Keswick Literary and Scientific Society. In some country towns the museums are apt to be dusty, ill-lighted places, containing curious things from all parts of the world, but nothing of the district. In this almost every object is specially calculated to illustrate the topography, the natural history, or geology of the district; that is what all museums should aim at (hear, hear). Among the names to be specially mentioned there were two—the first Mr. Flintoft, the maker of the model, which for nearly half a century has been studied by almost every tourist. Mr. Flintoft was a stranger—a Yorkshireman—but like so many others he was fascinated by the mountains and lakes, and spent months and years in making the drawings and levels for the model, which as the work of a single man is exceedingly remarkable and valuable. The model at Mr. Mayson's, from the ordnance survey,

might be more accurate, yet anyone wishing to get a general idea of the district could not get a better one than from Flintoft's model. There was one other name, but his removal being so recent, one could not refer without feelings of regret to James Clifton Ward, whose marvellous works they could see around them. He was the great illustrator of the geology of this region. When they saw that great map of his, all those rock collections, those drawings and sections, they must admit he had raised for himself a monument in the place, which the speaker hoped would remain for many, many years. Clifton Ward was anxious to communicate his own knowledge of the district for the benefit of all who cared to avail themselves of it. Those on the Geological Survey knew what a painstaking, conscientious man he was. His map, 101, S.E., is one of the most remarkable works; the district had been a puzzle for years, but Clifton Ward worked it out, and now the geology of few parts of the country is better known than this. After alluding to the work of Professor Sedgwick, and of Harkness and Nicholson (who, with the aid of Joseph Graham, did for the Skiddaw Slates what Clifton Ward did for the Volcanic Series), the speaker referred to the work of the Crosthwaite family, and their excellent museum which existed for nearly a century, and part of which is now to be found in the British Museum. They interested themselves in the natural history of the district, and the present representative of the family, Mr. J. Fisher Crosthwaite, is one of the most popular men of the town. He next briefly touched upon the labours of Jonathan Otley. As present day workers among fossiliferous remains, the speaker mentioned Mr. Christopherson and Mr. Kinsey Dover, who he hoped would continue their researches. Speaking for the members of the Geologists' Association, he said they were exceedingly obliged to the members of the Literary and Scientific Society for their reception, and especially to Mr. Kinsey Dover, who had consented to act as one of their directors.

The President then gave a short sketch of the geological features of the neighbourhood, repeating briefly some of the points of his previous lecture (July 1). By the aid of Mr. Ward's splendid map and sections, in conjunction with the numerous specimens, this was a comparatively easy task. Immediately afterwards the party, largely reinforced by members of the Keswick Literary and Scientific Society, left the Town Hall, and proceeded to inspect the quarry at Castlehead. This beautifully wooded hill is entirely

N. DIAGRAMMATIC SECTION THROUGH KESWICK, MODIFIED AFTER S.
CLIFTON WARD.



1. Skiddaw Granite. 2. Spotted and Chiastolite Schists. 3. Skiddaw Slates. 4. Castlehead eruptive trap (doleritic). 5. Volcanic Series.

composed of an eruptive rock, which burst through the Skiddaw Slates, most probably in early Silurian times, and may be regarded, according to the late Mr. Clifton Ward, as the plug formed in the lower portion of a volcanic vent which contributed to the enormous outflow of lava and ashes occupying the base of the great group of rocks, formerly known as the "Green Slates and Porphyries," but more recently as the "Volcanic Series of Borrowdale." The composition of the well-known bedded lavas of Falcon Crag is sufficiently near that of the eruptive rock of Castlehead to render the supposition a very probable one. To inspect this remarkable series of lavas and ashes the party accomplished the feat of scrambling up Catgill—by no means a difficult undertaking for the Keswick men, but not so easy for less experienced mountaineers. Nevertheless the enthusiasm of all, aided by fine weather and stimulated by the beauty of the scenery (so thoroughly appreciated by the late poet laureate, Southey) enabled the party to triumph over all difficulties. The great lava bed of Falcon Crag, 150ft. thick, consisting of a dull blue whin—not at all a handsome rock in hand specimens—is seen to rest upon a bed of volcanic ashes in the middle part of Catgill; beyond this the stream turns at right angles to its previous course, occupying a line of fault which runs for some distance at the back of Walla Crag. A very sharp climb brought the party to the little waterfall precipitating itself into Catgill from the east, and here they noted the very clearly indicated junction of a lava, having a vesicular base, with some

green ash partially cleaved and distinctly bedded. The clinometer showed a dip of 9° south-east. Most of the beds on this side dip in the direction of Bleaberry Fell, which occupies a synclinal, as is so often the case with high grounds.

The next move was to the summit of Falcon Crag, where Mr. Jenkinson pointed out the topography. The view is very extensive, and enables the spectator to contrast the scenery of the two sides of Derwentwater, the smooth and rounded outlines on the west being due to the forms assumed by the Skiddaw Slates under the hands of that grand old sculptor, Time, with rain and frost for his most effective chisels. The Volcanic Series on the south and east refuse to take so smooth a polish. A good instance of this may be seen on the summit of Falcon Crag itself, where the pressure of ice during the glacial period has most distinctly rounded off *(moutonnée)* the south side, but the rugged nature of the rock (a rather coarse ash on the summit) is beginning to show itself once more under the influence of the ordinary agencies of denudation. The ice during the glacial period filled up the valleys to about 1,500 feet on the Bleaberry Fell range, each valley system being for the most part independent, though in one case the watershed between Bleaberry Fell and Seat may have been overridden so as to give passage to certain boulders of the Armboth elvanite. Regarded as a whole the Lake District manufactured its own boulders, and as it kept the Scotch and all other rocks from its mountain slopes the glacial phenomena of the region affords no colour to the notion of an universal ice cap.

Heavy was the pull and many the rests between the top of Falcon Crag and the summit level of the walk, a little to the south of Bleaberry Fell, whence the descent to the brow of Shoulthwaite Gill was easy. Here the chief difficulties of the day commenced, and as the leader was determined to find the lava which occupies the base of Iron Crag at the south end, something like a disruption of the party occurred. However, the lava was found, the steep descent was safely accomplished by all, and the mural aspect of Iron Crag duly appreciated in safety from the bottom. Interesting specimens of rocks were secured in the passage down Shoulthwaite Gill, including some remarkably fine bedded ash, and the garnet rock of Sippling Crag. So fresh were the majority on reaching the Ambleside road that a large number turned down the Naddle valley, where they ransacked the walls for specimens of the beautiful red

porphyry of Armboth, which is plentifully distributed throughout this region. The principal part of this number, disdaining the high road, then tried a short cut across the bogs below Goose Well, and finally crowned a well-spent day by a visit to the Druid's Circle on their way to Keswick.

On Wednesday morning train was taken to Threlkeld Station, whence the party visited the quarry in the St. John's quartz-felsite. Mr. Bullen expressed his regret that he had not been advised of the intended visit, but kindly afforded every facility for exploring this very interesting section, which shows a faulted junction with the Skiddaw Slates. The stone, believed by Mr. Ward to be the result of the metamorphism of a mixture of the Skiddaw Slate and Volcanic Series, is being largely quarried for paving, and the manager speaks in sanguine terms of the future development of the works. It is thought that, as the quarry advances further into the hill, the rock will assume a more granitoid aspect.

The next move was for the western shoulder of Saddleback, past High Row, and up Glenderaterra. The Skiddaw Slates of this region dip for the most part at moderate angles towards the north-west. They are black and glossy, but with very few traces of fossils. When nearly through Glenderaterra the metamorphic belt, containing crystals of chiastolite, was reached. That this belt really is metamorphosed Skiddaw Slate, and not some underlying formation, has been proved indisputably of late, by the discovery in the Chiastolite Slate on Skiddaw top of a well preserved trilobite, now in the Keswick Museum, supplemented by the discovery of a graptolite in a similar matrix, the latter specimen being in Mr. Kinsey Dover's collection. No junction of this rock with the "Spotted Schists" was noticed, but the presence of these latter soon became manifest on the hill side. Leaving the track the party started up Roughten Gill to the waterfall, where "Spotted Schists" are observed *in situ* with a sort of foliation dip of 70° to the south-east. This was the farthest point from home, and the return route was past the hill where the "Spotted Schists" have yielded so many specimens of the rock harmonicon, and thence into Sinen Gill, where the junction of the granite with the micaceous variety of the "Spotted Schists" occurs. It is the action of this granite, doubtless in connection with the much larger mass in the Caldew Valley, which has produced the metamorphism of the slaty beds within a certain distance of its influence. This at least is the generally accepted view, and the discovery mentioned

above strengthens the metamorphic theory. The scenery of Skiddaw Forest is decidedly gloomy in character, and some of the party were not sorry perhaps to emerge once more from the dark defile of Glenderaterra into the sunlit woods of Brundholme which overhang the merry Greta, whence the descent towards Keswick was rapidly made, the ladies taking the lead on this occasion. A call was made by the way at Myrtle Grove, where, at the invitation of Mr. Kinsey Dover, the members of the Association examined his fine collection of fossils from the Skiddaw Slates, the result of some years of research, and consisting chiefly of graptolites, which are the characteristic forms from these beds, for they are the chief fossils hitherto obtained. Mr. Christopherson and Mr. Peter Harrison, of Keswick, had also obtained many similar specimens. At the request of the President, Professor Morris offered a few remarks on their nature. He pointed out that many different opinions had been advanced as to the systematic position of the graptolites, but the most favoured view considered them to be allied to the living sertularian zoophytes or "Sea Firs." Simply expressed, the typical form consists of a row of horny cups united at their bases by a common tube into which they open, and generally supported by a fibrous rod which projects from one or both ends of the polypary, in which they differ from their modern allies. The portions preserved constitutes the skeletons only of the composite colonies or polypary of the ancient graptolites, but there can be little doubt they were composed of flexible horny material, similar to the outer chitinous investment of the colonies of the modern sertularians. The more complex forms are produced by the combination in different ways of the above simpler factor, hence these combinations are divided into numerous genera of the family Graptolitidæ. Some have a simple row of cells on one side only as *Graptolites*, some have double rows as *Diplograpsus*, others present a combination of the above two forms as *Dicranograpsus*, and a fourth type consists of four series of cells as *Phyllograpsus*. Some genera are peculiar to the Skiddaw Slates, as *Tetragrapsus*, *Phyllograpsus*, and three others, but in the Quebec rocks of Canada, which are considered to be of the same geological age, or Lower Silurian, about eight genera occur which are common to both series. The specimens obtained by Mr. Dover are finer and larger than the Canadian forms, and from their state of preservation will perhaps assist in clearing up some further points in their structure and affinities. In conclusion, Professor Morris,

after alluding in a graceful manner to the Hudlestons as being a Cumberland family connected with Hutton John, and also the former owners of Millom, thanked the President on behalf of the Association for the admirable manner with which he had conducted the members for the last two days, and for the amount of information given respecting the structure of a district new to most of them, so replete with interest both as to its geological character and features, so that the present may probably be regarded as one of the most instructive excursions of the Association.

Thursday saw the party at Lodore, where the Skiddaw Slates form a triangular wedge of low ground faulted against the mural rocks of the volcanic series, which are themselves cleft by a subordinate fault forming part of that remarkable chasm. Thence into Troutdale, where some of the members probably saw live char for the first time. A tongue of Skiddaw Slates runs up this mountain glen for some distance, forming the floor of the valley. A low pass leads over into Borrowdale, and here the party, after inspecting the cleaved rough ash of these well-known slate quarries, just glanced at that enormous mass of fallen crag known as the Bowder Stone, and then hurried on in carriages through Rosthwaite and Seatoller towards Honister Pass. Fortunately the day was fine, but the rains of a week or two ago had left their marks, and generally it may be said that the western descent of that celebrated pass is much the same as it was forty years ago. Buttermere was bathed in sunshine and looked unusually lovely. There is considerable analogy between the geological structure of this valley and that of Derwentwater ; both are excavated in the Skiddaw Slates at their junction with harder rocks. In this case the Buttermere " Syenite " supplies the place of the volcanic series. It is a handsome red rock, and will probably be worked some day. Scale Force occupies a cleft in the " Syenite " close to a faulted lode charged with red oxide of iron. The chasm has been cut by water, determined probably by the fault. The adjacent Skiddaw Slates are hardened, but no crystalline action has been set up. A portion of these slates has been carried to the top of Red Pike. Later in the day Mr. Blake discovered a junction between the Slates and "Syenite," a little east of Scale Force. There are no signs of gradual change, the contrast is complete, and the "Syenite" has all the appearance of an instrusive rock.

On Friday the party left Keswick in somewhat unfavourable weather, but matters improved ere the carriages reached Grasmere,

where the party were met by Mr. C. E. De Rance, F.G.S., who carried out the Geological Survey of the Ambleside district between 1872-4. He pointed out the watershed that had just been passed at Dunmail Raise, between Wythburn and Grasmere, as part of the important central watershed crossing England from east to west, and which is crossed by passes at various elevations, ranging from little above the sea-level between St. Bees and Whitehaven, to 1,380 feet at Kirkstone Pass, that on Dunmail Raise being only 775 feet; through the latter will be carried the aqueduct of the Manchester Corporation Waterworks, conveying the waters of Thirlmere Lake to South Lancashire. Grasmere Lake was stated to be a rock basin, 80 feet in depth, probably scooped out by glacier action, evidence of which action may be seen on the slopes of the valley on either side, to 1,200 feet above the level of the sea.

A halt was called to examine similar phenomena at the bottom of Rydal Lake, where a glaciated *rôche montonée* rises to a height of 20 feet above the level of the water, and has been cut through by the Rothay in a narrow gorge, giving passage to the overflow of the lake. South of this spot the river, being deflected by a rocky barrier opposite Rydal Mount, suddenly changes its direction, and flows past the *rôche montonée* of Ambleside church, long ago described by Lyell, following the line of a fault which ranges down the valley.

After lunch at Ambleside, the party started by the footpath to Skelgill and Troutbeck, crossing the south-west slope of Wansfell, and passing over the higher beds of the Volcanic Series, which here contain a large amount of altered material resembling white china, which has the appearance of having eaten into the rock in an irregular manner. This substance has a generally baked appearance, and is occasionally cleaved in small, less altered patches, in which condition it has been called "white-ash," as a convenient name, but not as implying any theory of origin. It is much traversed by small mineral veins, and the whole rock is occasionally charged with a dust of sulphide of iron, and more rarely of sulphide of lead.

A halt was called on reaching the first eminence overlooking the Ambleside steamer landing-pier. The northern sky-line is made entirely of rocks of the Volcanic Series, which form the central watershed before referred to; the whole of the country visible consequently drains into Coniston or Windermere Lakes, and eventually into Morecambe Bay. The strike of the Volcanic Series

is about east and west magnetic, and corresponds with that of the cleavage; but as may be seen between Ambleside or Keswick the anticlinal axis of the bedding correspond to synclinals in the cleavage.

Mr. C. E. De Rance stated that on sounding Lake Windermere he had found it to be 39½ fathoms deep opposite Wray Castle close to the western shore, and as the surface of the lake is only 134 feet above the sea, the bottom of the water is 100 feet below mid-tide level; and it was pointed out that the total depth of Windermere is somewhat greater than that of the English Channel between Folkestone and Boulogne. Moreover, when the river Leven has cut a deeper groove at the foot of the lake, and the surface of the lake is proportionately lower, the shallower part around Belle Isle at Bowness will become land, and Windermere will become two distinct lakes.

Looking southward, the lower lake was stated to be 20 fathoms deep, and the outline of the sea was pointed out, in the far horizon, broken by hills of Carboniferous limestone, which range from Ulverston, through Cartmell and Grange.

The Skelgill Beck was then ascended, and the succession of Coniston Limestones, Mudstones, and the overlying Graptolitic Shales observed, and fossils collected therefrom. Ultimately the party returned to Ambleside by way of Stock-Ghyll Force.

ORDINARY MEETING.

NOVEMBER 4, 1881.

W. H. HUDLESTON, ESQ., M.A., F.G.S., PRESIDENT, in the Chair.

The list of donations to the library since the last meeting was read, and the thanks of the Association were returned to the donors.

The following were elected members of the Association:—Jas. Moon, Esq.; H. Nenn, Esq.; Prof. P. Martin Duncan, M.B. Lond., F.R.S., F.G.S., &c.; John Evans, Esq., D.C.L., F.R.S., F.G.S.; Alfred Ewen, Esq.; E. B. Tawney, Esq., M.A., F.G.S.; John Brown, Esq., F.G.S., and Chas. H. Watkins, Esq.

The President then delivered his opening address.

ADDRESS

AT THE OPENING OF THE SESSION, 1881-82.

NOVEMBER 4TH, 1881.

BY THE PRESIDENT,

W. H. HUDLESTON, Esq., M.A., F.G.S., F.C.S.

ON DEEP-SEA INVESTIGATION.

It has now for so many years been the custom for the President of this Association to open the Session with a communication dealing with some subject likely to be of interest to the members, that I need not apologise for following an example of such long standing. Last year my immediate predecessor was able to seize on a convenient opportunity for dealing with a subject of supreme interest to us all, viz., the origin and development of ourselves, and thus, through his able treatment, the Association possesses a history of itself such as few societies can boast of. No similar opportunity presents itself to-day, and I must accordingly fall back on one of the many topics which may be presumed to connect themselves more or less with geology.

The recent issue of three volumes of the long-promised Challenger. Reports, being the first instalments of the fourteen or fifteen quartos which are to form the complete work, has served to direct renewed attention to the subject of deep-sea investigation. Besides the hydrographical, physical, and chemical details, the zoological reports will include about fifty distinct memoirs; yet, in spite of this enormous amount of work, it may be interesting for some of you to know that a few classes of creatures are still unappropriated.

It might perhaps be deemed somewhat premature to go into these questions until *all* the Reports had been published, but we must remember that over five years have elapsed since the return of the Challenger, and that during the interval important preliminary reports have been issued and discussed. Moreover, the

results of the United States coast survey under A. Agassiz, in the Caribbean Sea and Gulf of Mexico, are being rapidly brought out, whilst during the same interval the Norwegian North Atlantic expedition has contributed additional information, being a portion of the results of cruises during three years in succession.

On referring to our own "Proceedings," you will find that at the meeting in December, 1874, Dr. Carpenter delivered a lecture "On the Conditions which determine the presence or absence of Animal Life on the Deep Sea bottom." The lecturer began by observing that it would be unnecessary for him to point out to the members of the Association "that the foundation of the whole of geological science—that is, the interpretation of the phenomena presented to us in the study of the earth's crust—must be based upon the study of the changes at present going on upon the surface of the earth, including, of course, the depths of the sea."*

Without pledging ourselves to a too strict uniformitarianism, and with due reservation of all our rights to be guided by such evidence as shall from time to time fall under our notice, we cannot but give a general assent to the doctrine thus enunciated, though possibly, in the sequel, we may arrive at the conclusion that many of the phenomena of deep-sea investigation throw but little light upon the questions ordinarily presented to the geologist. Indeed, as regards the formation of deposits analogous to those of the several geological epochs, there is more perhaps to be learnt from such a work as that by Delesse, entitled "Lithologie du Fond des Mers," of which we have a useful abstract by Lebour in our "Proceedings," having special reference to the British seas.† Nevertheless the discoveries of the last twenty-five years in the depths of the ocean have opened out to us all a new world, besides serving to correct some errors, which stood in the way of the geologist, as well as of every other student of nature, past or present.

In dealing with these discoveries, the great difficulty has been to select from the large amount of published matter such portions as might seem to be of especial interest to you. In order to facilitate reference, the subject has been divided into four sections, any one of which would by itself form the text for an evening's discourse.

Section I. gives an exceedingly brief sketch of the history of deep-sea exploration.

Section II. deals with hydrography and physical conditions.

* "Proc. Geol. Assoc.," vol. iv., p. 176.

† Vol. iv., p. 158.

Section III. with the nature and occurrence of deep-sea deposits.

Section IV. with life on the deep-sea bottom.

I. *History of Deep-sea Exploration.*—To submarine telegraphy we owe the first systematic attempts at deep-sea sounding, which had been rendered practicable by a recent American invention. In 1857 Commander Dayman was engaged in the survey of the Atlantic for the purposes of the cable, and this, if we except the work of the Americans on board the Dolphin and the Arctic, may be regarded as the commencement of accurate ocean hydrography; whilst Dr. Wallich in the Bulldog, three years later, may be justly deemed the "pioneer"* of deep-sea zoology.

In those days there were two errors that had to be especially combated. One was that below a certain depth the great mass of ocean water had a uniform temperature of 39° F.—the point of maximum density of fresh water;—and it is curious to note that even so recently as 1868 no less a person than Sir Wyville Thomson observed in a letter to Dr. Carpenter "that the temperature of deep water seems to be constant for all latitudes at 39° F."†

But the notion that the zero of animal life was reached at a depth of 300 fathoms was an error of far more consequence to geologists. This idea is commented on, and its origin explained, by Dr. Carpenter in the lecture previously mentioned, wherein he concludes that Forbes' dictum is in the main true for the Mediterranean, which also further differs from the ocean in having a uniform temperature of 54·7° F. for all depths below 100 fathoms. Yet the depths of the Mediterranean are not wholly destitute of life, for after the Sardinian cable had been fished up for repairs from 1,200 fathoms in 1860, Prof. Fleeming Jenkin in the following year determined an adherent coral to be a variety of the well-known deep-water species, *Caryophyllia borealis.* This Sir Wyville Thomson considers to have been the first absolute proof of life at great depths, though perhaps the thirteen historic star-fish of Dr. Wallich clinging convulsively to the sounding-line might also put in a claim to this distinction.‡

Every now and then, in similar fashion, a witness had risen up

* Moseley, Lecture at Royal Institution, March, 1880.

† "Depths of the Sea," 1st edition, p. 52.

‡ The substance of the facts relating to this interesting capture was communicated to the Editors of the "Annals and Magazine of Natural History," and published by them in December, 1860.

from the deep to testify against the prevailing doctrines. Yet the orthodox clung to their faith as tightly as did the star-fish to the line, and the revelations of Wallich seemed in danger of being set aside, though there had not been wanting dissentients even before the days of deep-sea soundings. Amongst the most distinguished of these was Prof. Lovén, who, at a meeting of the British Association in 1844, observed, " As to the point where animal life ceases, it must be somewhere, but with us (*i.e.*, in Scandinavia) it is unknown." Nineteen years afterwards he was able to refer to the results of the Swedish Spitzbergen expedition of 1861, where dredging had been carried on with success in 1,200 fathoms.* Shortly afterwards Prof. Sars, in 1864 and 1868, obtained important results off the Lofoten Islands, though not below 450 fathoms. To the well-known work of Count Pourtalès on the other side of the Atlantic in 1868, it is hardly necessary to refer.

This brings us down to the work of the Lightning and the Porcupine from 1868 to 1870, when, as regards the seas adjacent to the British Islands, and even in those more remote, Dr. Carpenter, Sir Wyville Thomson, and Dr. Gwyn Jeffreys succeeded in convincing every one of the existence of life at great depths. Nor should I forget to mention that in this latter year one of our own members, Captain Marshall Hall, along with Mr. Saville Kent, did some good zoological work in the yacht Norna, off the coast of Portugal. The crowning point of these most interesting and plucky cruises may be said to have been reached when the dredge was hauled up from a depth of 2,435 fathoms in the Bay of Biscay with good examples of the five invertebrate sub-kingdoms. This victory over difficulties previously insuperable was gained at a station about as far to the west of the Land's End as London is to the east of it, just at the foot of the great submarine slope which constitutes the eastern boundary wall of the old continent.†

* On this occasion the Swedish naturalist expressed an opinion that wherever the bottom is suitable " a fauna of the same general character extends from pole to pole through all degrees of latitude." " Depths of the Sea," p. 269.

† A little to the south of the parallel of Ushant.

The dredge bag contained 1½ cwt. of " very characteristic grey chalk-mud—mostly as an amorphous paste, with but a small proportion of the fresh shells of *Globigerina* and *Orbulina*." " Depths of the Sea," 1st edition, p. 96.

It is interesting to remember that this feat was performed in time for the veteran Sir Charles Lyell to quote the results in the latest editions of the " Principles of Geology." 11th edition, 1872; 12th edition, 1875.

II. *Hydrography and Physical Conditions.*—Having thus briefly alluded to the events which led to the memorable voyage of the Challenger, I will now proceed to consider some of the general results obtained under the above headings by the various expeditions.

The average depth of the ocean is calculated by Dr. Carpenter, as the results of the investigations of the Challenger, at 2½ miles, or about 12,000 feet.* The narrow zones of shallow water which usually margin the ocean along the coasts of continents and continental islands, such, for instance, as that portion of the Atlantic within the 100 fathom plateau, are not to be accounted as belonging to the ocean in a hydrographical sense. The true border of the ocean is the edge of the great submarine slope which conducts with a gradient not exceeding those on some of our railways to the vast abyssal plains. These plains are on the whole pretty level, but with a bulge here and a depression there, ranging from about 1,700 fathoms to 4,640 fathoms.†

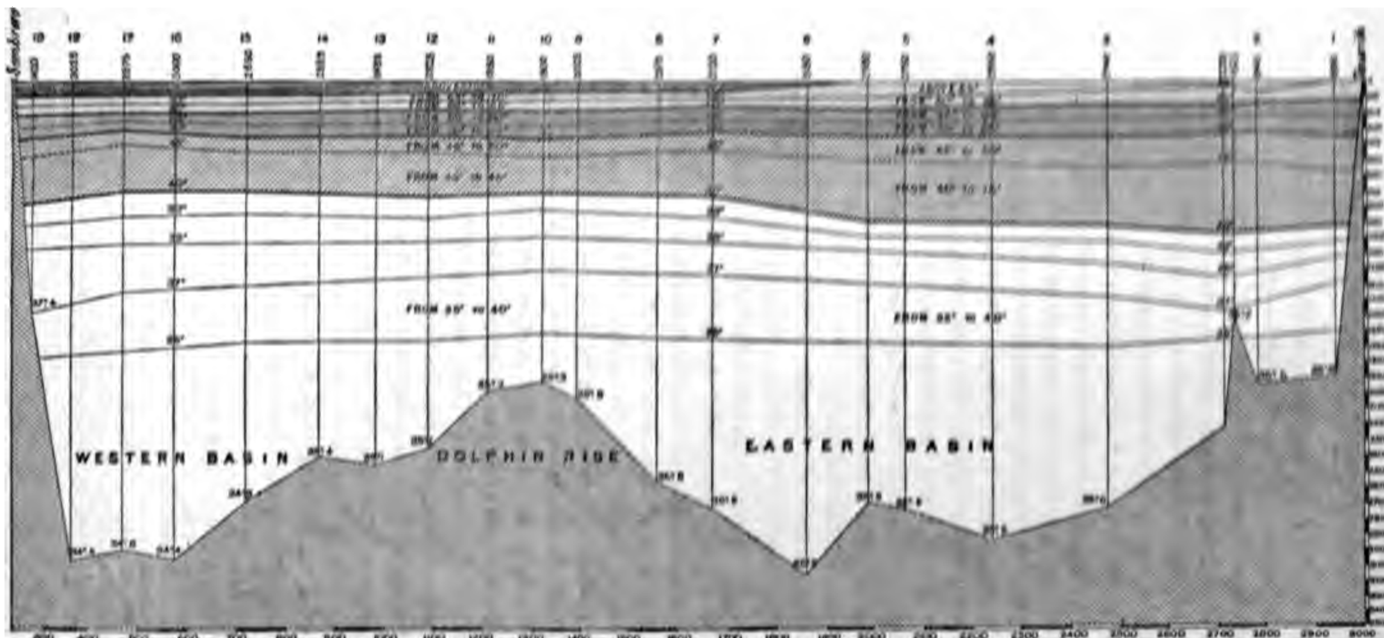
The section of the North Atlantic between the Canaries and the West Indies (Fig. 1) may be regarded in some respects as an average specimen of an ocean-bed contour. In this case the bulge in the middle forms part of the Dolphin ridge, but there is no very marked depression, the maximum depth shown in the section being 3,150 fathoms. Owing to the difference between the vertical and horizontal scales, the steepness of the sides is tremendously exaggerated. This section is, however, defective in one respect, viz., that, being drawn between two islands, it does not show that peculiarity of a submerged shallow plateau which is so characteristic of the edge of the great continents. This feature is better seen in Fig. 2 (New York to Bermuda), where the difference between an island slope and a continental slope is at once perceived, in the fact that the edge of the latter is submerged. Moreover, it so happens that the steepest slope known is at Bermuda, where there is an inclination of nearly twenty degrees from the edge of the reef to 2,000 fathoms.‡ For the reasons above detailed, Dr. Carpenter declares that the term "basin," as applied to the

* "Proc. Roy. Inst.," vol. ix., part 3, p. 268. See also "Nineteenth Century" for 1880.

† The deepest sounding of the Challenger was in 4,475 fathoms. Dr. Gwyn Jeffreys seems to be of a different opinion on the question of these moderate slopes. See his Address to the Hertfordshire Field Club, 1880. "Trans.," vol. i., part 5, p. 173, *et seq.*

‡ Moseley, *loc. cit.* on the authority of Capt. Tizard.

FIG. 1.—CANARIES TO WEST INDIES. CHALLENGER HYDROGRAPHIC REPORTS.



oceans, is a misleading one, a truer representation of an oceanic depression being that of a "tea-tray."

Some of the leading results of deep-sea sounding may be gathered from the map showing the distribution of deposits on the deep-sea bed (Fig. 3, page 257). The deep basins are laid down from the chart at the end of Mr. Moseley's "Notes by a Naturalist on the Challenger." As a general result, it is evident that the Pacific is deeper than the Atlantic, whilst the great Southern Ocean, or subantarctic water-belt, shallows materially towards the south. The greatest depths of the Pacific, as well as the widest areas of deep water, incline towards the Asiatic side. They also lie almost wholly north of the equator, and the same may be said of the Atlantic, from which it follows that the northern hemisphere contains not only the greatest area above sea-level, but also the greatest area below the 3,000 fathom level, and must consequently present a much greater amount of rugosity than the southern hemisphere.

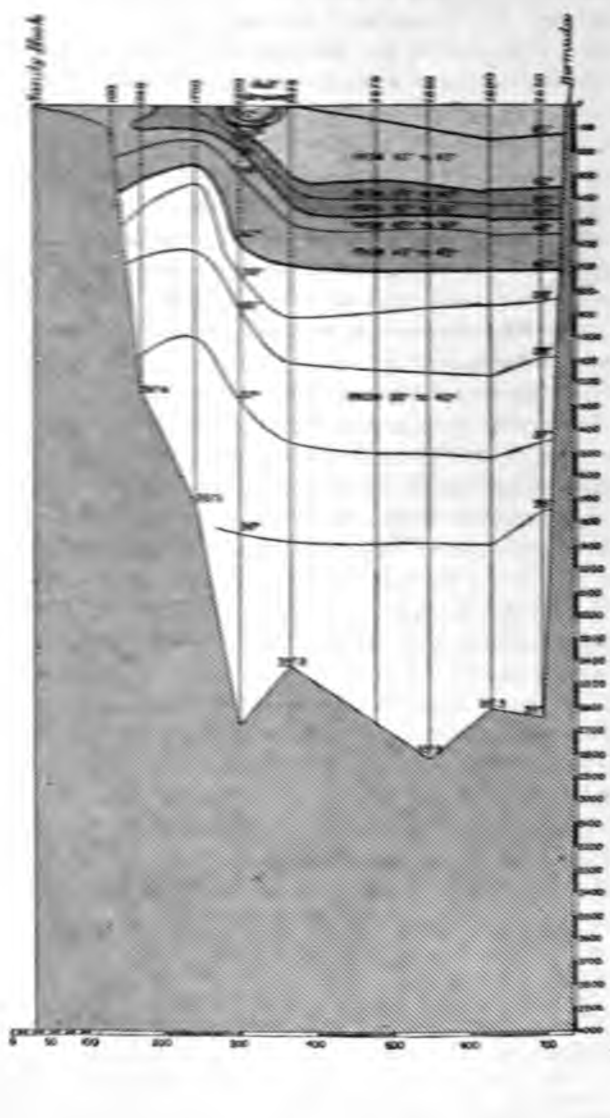
There is another fact in connection with extreme depths to which I may draw attention: it is perhaps a mere coincidence, but still a curious one. The deep sounding of 3,875 fathoms (23,250 ft.) in the Atlantic, off St. Thomas, is so close to the American side as to be regarded in relation to the New World, and accordingly we find this depth approximates in vertical range to the loftier peaks of the Andes.* On the other hand, the deep sounding off the Kurile Islands, in the N.W. Pacific, of 4,655 fathoms (27,930 ft.), is equally connected with the eastern margin of the Old World, whose loftiest summit, Mount Everest, is about 29,000 feet.

The subject of ocean currents is only indirectly connected with the deep-sea, as these appear to be mainly superficial. But, since the Florida current, or American Gulf Stream, figures so conspicuously in all speculations as to the past and present climate of these islands, it is only right to draw your attention to a section of the volume of this famous body of water before it begins to split up. On consulting Fig. 2, you will perceive that it is tolerably superficial, extending no more than 100 fathoms below the surface, with a breadth of 60 miles.† Its temperature is about 10° F.

* Chimborazo, 21,424 ft.

† Captain Tizard speaks of the American Gulf Stream running at a rate of three miles an hour for a width of 15 miles, and thus discharging 108 cubic miles per day of heated water into the North Atlantic. "Challenger Hydrographic Reports," No. 7, p. 12. He would thus seem to limit the central portion of the current to a breadth considerably less than that assigned, in the text, to the entire stream.

FIG. 2.—NEW YORK TO BERMUDA. CHALLENGER HYDROGRAPHIC REPORTS.



higher than the water in which it floats, except on the side where it meets the Labrador current, and there the contrast is extreme. It is for you to judge whether the American Gulf Stream, such as you see it in Fig. 2, is capable of performing the feats attributed to it, or whether, on the other hand, the so-called Gulf Stream on this side of the Atlantic is not the result of a series of complex causes, of which the original Florida current is only one amongst many.*

The temperature of the deep-sea is perhaps more widely known than any other of the physical conditions of the ocean. The sections in Figs. 1 and 2 for the most part speak for themselves. And if we took a *longitudinal* section from the equator to the poles, we should see the several zones of temperature cropping out as we receded from the equator, until at last the temperature of the bottom at the equator is about the temperature of the surface in polar waters.

Such are the facts; but what is the explanation? When Dr. Carpenter gave to the Association the lecture to which I have so often referred, he regarded the phenomenon as due to a slow and imperceptible underflow of cold, dense water from *both* poles, meeting at the equator, and slowly welling up, to be returned north and south in a warm surface overflow equally slow and imperceptible. The force which set this machinery in motion was difference of specific gravity.

The investigations of the Challenger, made subsequently, seem to have demonstrated that there is no such underflow of cold water from the Arctic Ocean which anywhere approaches the equator, but that the sources of cold water at the bottom of the equatorial seas are wholly from the Antarctic or Southern Ocean. To make this clear, it would be necessary to exhibit an enlargement of the map showing the deep basins of the Atlantic.†

However, the leading facts may be thus stated. You remember that the Atlantic is divided by its median bulge, known in different

* The fact is that when people on this side of the Atlantic speak of the "Gulf Stream" they usually mean the mass of warm oceanic water which impinges on the N.W. coasts of the Old Continent, and sends off its streams into the western portion of the palæarctic seas. It is not at all intended to underrate the importance of these currents, which even bring West Indian fruits to the shores of the Varanger Fjord; nay, it is the very magnitude of the results which renders it doubtful how far the original Florida current, such as we now know it to be, is to have the sole credit of heating the north-west seas of the Old World.

† "Challenger Hydrographic Reports," No. 7. Plate vi.

parts as the Dolphin ridge, the Connecting ridge, and the Challenger ridge, into an east and west basin of over 2,000 fathoms. Well, the western basin is nipped in two by a cross ridge, starting from the coast of South America, somewhat to the north of the mouth of the Amazon. Thus there are three basins, or "tea-trays," as Dr. Carpenter would prefer to call them. Of these the south-western one has a bottom temperature much below that of the others; under the equator the bottom temperature of this basin is below 32° F. in some places. In the north-west basin, even at the enormous depth of 3,875 fathoms, the bottom temperature is uniform at about 34·5° F., whilst the eastern basin has a uniform bottom temperature about half a degree higher.

Submarine ridges are the chief agents in keeping out the very cold polar waters, and thus the Icelandic ridge of about 500 fathoms, which bars the ice-cold bottom waters of the Norwegian Sea from the North Atlantic, is perhaps a principal agent in keeping up the temperature of the eastern basin, for the Lightning Channel is too narrow, and, on the whole, too shallow, to admit the passage of any important body of ice-cold water from the Norwegian Sea.*

The composition of sea-water cannot be altogether overlooked. The very deepest portion of the ocean contains abundance of oxygen, and according to the determinations of Mr. Buchanan quite enough and to spare for the little life there is there. As regards organic matter, the same chemist found traces, but only slight traces of its presence, and in this way he disposed of *Bathybius*, that all-pervading *moner*, which was supposed to line the floor of the ocean with its sheets of protoplasm. Silicic acid has also been found by Tornöe in the waters of the Norwegian Sea, but only to the extent of some fractions of a milligramme per litre.†

The much-vexed question of free carbonic acid still remains. You are aware that, besides common salt, there are very appreciable amounts of magnesia and lime in sea-water, chiefly in combination with chlorine, bromine, or sulphuric acid. There is also some carbonic acid, and the determination of this, both as to quantity and status, was an important item in the Challenger laboratory work.

There had always been a difficulty about disengaging carbonic

* Mr. Buchanan is of opinion that the temperature of the lower layers in the Pacific is, to a certain extent, influenced by northern waters.—"Journal Chem. Soc.," 1878.

† This agrees with Thorpe and Morton's determinations of silicic acid in the waters of the Irish Sea.—Tornöe, "Chemistry of the Norwegian North Atlantic Expedition."

acid gas from sea-water—a difficulty easily explained by the light of subsequent discovery. The whole story forms one of the most curious episodes in the history of chemical analysis, if the results detailed by Herr Tornöe are to be relied on.* Mr. Buchanan, acting upon the ideas of Jacobsen, and strengthened by his own experiments, had concluded that the unwillingness of sea-water to part with its carbonic acid on boiling, was principally due to the sulphates, which he was therefore in the habit of precipitating with chloride of barium. In this way he found about 50 milligrammes of carbonic acid per litre in Atlantic surface water.† The Pacific water was found to contain less. The difference between the carbonic acid found on the surface and at the bottom was not great.‡ Mr. Buchanan made a number of experiments to detect the presence of carbonates in sea-water, with the general result that carbonates are never present except in small quantities, and in many samples they were absent altogether. The inference, therefore, to be drawn from these experiments was to the effect that the carbonic acid found was, for the most part, uncombined.

This large amount of free carbonic acid, under the influence of powerful pressure at great depths, was supposed by Sir Wyville Thomson to be one of the principal agents in removing the *Globigerina*-shells from the "red clay" areas. Herr Tornöe, on the other hand, declares that there is no uncombined carbonic acid in sea-water, and he fortifies his position with two most important facts. In the first place, he finds that the reaction of sea-water is alkaline, whereupon Prof. Duncan, in a letter to "Nature," exclaims—"What a comfort for *Globigerinæ* and coral reefs!" Secondly, it turns out that protracted boiling with evaporation decomposes simple carbonates in the presence of soluble salts of magnesia; this is owing to the unstable character of carbonate of magnesia.§ Finally, Herr Tornöe concludes, as the result of many

* Tornöe, *op. cit.*

† "Proc. Roy. Soc.," vol. xxiv., p. 604.

‡ On the whole, there was less carbonic acid in warm than in cold water. An average of results gave 45 milligrammes per litre for ocean water. Jacobsen, in the North Sea, had an average of 88·6 m. per litre, but he experimented on green water, Buchanan on blue water. In the Antarctic Ocean, where such green water sometimes occurs, carbonic acid is present in marked excess. In lat. 65-42 S., for instance, occurred the maximum in bottom water, viz., 83 m. (depth 1,675 fathoms). Of the surface water the actual maximum—96 m. per litre—occurred between the New Hebrides and Fiji.—"Journal Chem. Soc.," 1878, p. 460 *et seq.*

§ On boiling a solution of carbonate of soda and sulphate of magnesia with due precautions, the whole of the carbonic acid is expelled.—Tornöe, *op. cit.*, p. 39.

determinations, that the waters of the Norwegian Atlantic contain 53 milligrammes per litre of carbonic acid as carbonate, and 44 milligrammes per litre of carbonic acid as bicarbonate. How far these results will bear investigation remain to be seen.

III. *Nature and Occurrence of Deep-sea Deposits.*—To us, as geologists, this is perhaps the most important part of deep-sea investigation; and, since much of the material is organic, it involves also a partial consideration of the fauna of the pelagic surface and of intermediate depths.

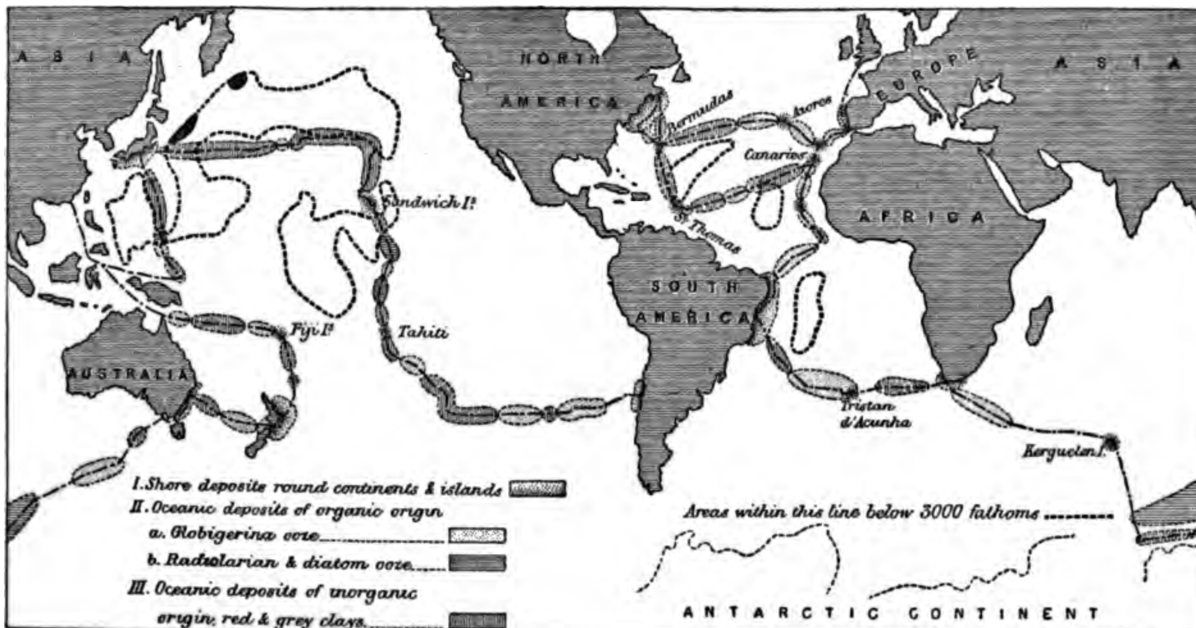
Mr. Murray* has classified the deposits met with during the Challenger voyage under the head of *Shore deposits, Globigerina-ooze, Radiolarian and Diatomaceous ooze,* and *Red Clays.* To these may be added the *Biloculina*-ooze of the deeper parts of the Norwegian Sea. The accompanying map (Fig. 3) shows the distribution of these deposits as far as the track of the Challenger to Valparaiso in 1875. It accompanies Mr. Murray's preliminary report.

1. As regards the *shore deposits,* we may, on the present occasion, neglect all but the green and blue muds met with near the margin of the continents and larger islands. The deep-sea itself is affected by the mechanical degradation of the land for short distances, and floating ice occasionally gives both the coarser and finer materials a passage out to sea to within about 40° of the equator in some latitudes. Even the finer materials derived from the wear of the coast, or brought to sea by rivers, are deposited almost entirely within two hundred miles of land.† In depths from 50 to 700 fathoms these shore deposits are often of a green colour from the presence of glauconite; below 700 fathoms they are usually blue. About 150 miles from the shores of a continent the mud loses its blue colour and becomes reddish or brown; also, instead of the particles of mica and rounded pieces of quartz found nearer the land, pumice and volcanic minerals are more noticeable.

These green and blue muds have been found to prevail in all the enclosed seas visited by the Challenger, as the Arafura, Banda, Celebes, and China Seas, likewise in the inland sea of Japan. In all these cases the carbonate-of-lime organisms would appear to be removed from the sea-bottoms at a less depth than on open coasts by 400 or 500 fathoms.

* "Proc. Roy. Soc.," vol. xxiv., p. 518.
† Murray, "Proc. Roy. Soc. Ed.," 1876-7, p. 53.

FIG. 3.—SKETCH-MAP SHOWING THE TRACK OF THE CHALLENGER AS FAR AS VALPARAISO IN 1875, WITH THE NATURE OF THE DEPOSITS AS DEDUCED FROM THE SOUNDINGS.



[Based upon Mr. Murray's map, "Proc. Roy. Soc.," vol. xxiv., pl. 20.]

The dark spots within the 3000 fathom line, in the north-west Pacific, indicate the deep soundings of the Tuscarora.

Perhaps the most interesting feature in connection with these shore deposits is the abundance of glauconite or other green silicate, which occurs both as grains and as casts of the interiors of calcareous organisms whose tests have disappeared. The phenomenon is mainly confined to depths less than 700 fathoms. Below this depth both glauconite grains and casts are but sparingly distributed. Glauconite was more especially noticed off the coast of Portugal, and in the Indian section of the Southern Ocean off the Crozets, in grey mud at 600 fathoms, where the casts were of a pale straw-colour, unaccompanied by any grains; and again off the east coast of Australia, in 400 fathoms, when the casts were dark green, pale green, and dirty white. In some cases the smaller chambers of the foraminifera were green, whilst the larger ones were white or grey-coloured.

If time permitted, I might attempt to establish some connection between these green silicates, which go under the general term of glauconite, and the red clays of the deeper parts of the ocean. Their composition is probably not very different. The cretaceous glauconite is, for the most part, a hydrous silicate of ferric oxide, with a considerable amount of alumina, and very much smaller quantities of magnesia and potash. The great peculiarity is that a ferric silicate, or one where the ferric oxide predominates, should be green, and not red. Allusion has been made to this circumstance by Prof. Morris in the notes to his lecture on the "Geology of Croydon."* The ultimate source both of glauconite and of red clay must be sought mainly in the products of decomposition of the varieties of pumice. As an exceptional instance of the occurrence of foraminiferal casts in red silicate (?), I will mention one in the S.E. Pacific, at a depth of 1,450 fathoms, on a bottom of *Globigerina*-ooze of a red colour, containing much pumice.† In this case the red substance had coated as well as filled the shell, thus affording an external and an internal cast connected by pillars representing the foramina. As a rule it should be noted that the casts of foraminifera occur very sparingly in *Globigerina*-ooze; the purest samples contain none.

2. This brings us to the consideration of the *Globigerina-ooze*, which is not met with south of 50° S., nor possibly much beyond lat. 60° N., but within these limits is, after the deep-sea clays, the most abundant of the oceanic deposits. It may be as well to bear in

* Published by F. Baldiston, "Chronicle" Office, Croydon.
† Lat. 18° 30' S., long. 173° 52' E.

mind that *Globigerina*-ooze, Radiolarian-ooze, and "red clays" all more or less commingle, or rather their constituents do. Nothing can bring out this fact more clearly than the 20 analyses of bottom samples from the section between the Canaries and the West Indies (see Fig. 1) given in the Appendix to Thomson's "Atlantic."* Under these circumstances it will be necessary to bear in mind that the sharp divisions shown on the general chart (Fig. 3) are merely adopted for the sake of contrast. Some of the intermediate varieties marked as "red clay," for instance, contain almost as much carbonate of lime as the adjacent *Globigerina*-ooze. On the other hand, however deep the deposit, or however red the clay, *Globigerinæ*, generally speaking, are found all over the bottom of the ocean; indeed, on only one or two occasions did Mr. Murray fail to detect some variety of pelagic foraminifera.†

As regards the materials composing the *Globigerina*-ooze, they are pretty well known. In the first place, it consists largely of the dead shells of *Globigerina*, *Orbulina*, and *Pulvinulina*, &c.‡

There is a vast difference between the highly ornamented shell of the foraminifer, whilst it floats on the warm and sunlit surface of the ocean, and the dead shells which are brought up from beneath. Another beautiful pelagic species has been called *Hastingerina Murrayi*;§ the shell is very delicate, and has only once been noted from the bottom. In a specimen obtained from the surface, "the sarcode of the animal was thrown out into bubble-like extensions between the spines of the shell, and over these expansions of the sarcode and along the spines, the pseudopodia moved freely and rapidly"‖—a charming picture of a pelagic foraminifer in a playful mood!

In the early days of deep-sea investigation, there was a general impression that *Globigerina* and its allies lived on the bottom. That was also the period when Atlantic mud was described as modern chalk. It is now stated by Sir Wyville Thomson,¶ by Prof. Huxley,** and by Mr. Murray,†† that these organisms live only on

* Vol. ii., p. 369.

† They appear to be quite absent in the Arafura Sea.—Murray, "Proc. Roy. Soc.," vol. xxiv., p. 523.

‡ For drawings of these forms see "Challenger in the Atlantic," vol. i., pp. 211, 214, 218.

§ *Op. cit.*, vol. ii., p. 294.

‖ Murray, "Proc. Roy. Soc.," vol. xxiv., p. 524, pls. 22 and 23.

¶ "Preface to Atlantic," vol. i., p. 12.

** Speech at Edinburgh after the return of the Challenger, reprinted in "Nature."

†† *Loc. cit.*, p. 535.

the surface and sub-surface waters of the ocean. Prof. Huxley says that when they die "their skeletons are rained down in one continual shower, falling through a mile or a couple of miles of sea-water."

When Sir Wyville Thomson, some years ago, first announced his change of opinion on this subject, such a piece of backsliding was very grievous to his late colleague in the Porcupine, Dr. Carpenter, who suggested that the *Globigerinæ* are pelagic in the earlier stage of their lives, and that, in consequence of the increasing thickness of their calcareous shells, they sink to the bottom, and there continue to live and probably to multiply.* Dr. Carpenter gave some excellent reasons for showing that the facts observed by the Challenger might bear a different interpretation, and he also dwelt especially on the difficulty of explaining the absence of *Globigerina*-ooze in certain areas of no excessive depth, such as the cold bottom between the Shetlands and the Faröes, on the hypothesis now adopted by Thomson.

It must be admitted that the disappearance of *Globigerina*-shells from the bottom of certain areas, whose surface waters are said to contain them in abundance, has not yet met with a satisfactory explanation. Still, is it right that, because we cannot explain certain phenomena, we should neglect such a piece of evidence as that of Mr. Murray? who says, "No living specimen of a *Globigerina*, an *Orbulina*, a *Pulvinulina*, or of the new genera found on the surface, which undoubtedly came from the bottom, has yet been met with."† This was written when the voyage of the Challenger was approaching its termination. More recently Mr. Brady, after examining all the Challenger collections bearing on this point, is said to have concluded that the main components of the mud are organisms which *do live* at the bottom.

There certainly does seem, as pointed out by Mr. Moseley, a curious connection between life at the surface and at the bottom, but a mere inference drawn from this connection can hardly outweigh the direct statements of Mr. Murray. At any rate, the court must adjourn the case for further evidence.

With regard to the rest of the calcareous elements of *Globigerina*-ooze, much of it consists of "coccoliths" and "rhabdoliths." Sir Wyville Thomson has concluded that "coccoliths" are the separated

* "Nature," Feb. 11, 1875. † *Loc. cit.*, p. 535.

elements of a peculiar calcareous armature, which covers certain spherical bodies—the "coccospheres" of Dr. Wallich. "Rhabdoliths" are the like elements of the armature of extremely beautiful little bodies—the "rhabdospheres" of Mr. Murray. From the drawings* on the wall you may perceive what these curious things are like: the spheres themselves are infinitesimally small, and the disconnected plates of their outsides must be proportionally smaller. No one appears to know much about the organic position of these things. The botanist and zoologist would seem to regard them with equal suspicion. It has been suggested that they are in some way connected with the Algæ; but whatever they are, they secrete a large quantity of carbonate of lime, and that circumstance entitles them to our notice when considering the deep-sea deposits, whose inorganic constituents and chemical composition will presently claim our attention.

The *Globigerina*-ooze, owing to admixture with organic silica in the form of Radiolaria and Diatoms, with "red clay" elements, and, where near the land, with rock débris, is far from being a pure calcareous formation. The best samples noted by the Challenger were in parts of the Southern Ocean off the Cape of Good Hope, where there is a wonderfully pure deposit in the neighbourhood of Prince Edward Island and the Crozets, consisting almost entirely of *Globigerina bulloides*, and containing possibly as much as 98 per cent. of carbonate of lime.† There are of course many gradations between a sample like this and an average specimen of what was called "modern chalk," such as that selected from the Atlantic mud for purposes of comparison with the white chalk of the south coast, and which happened to contain about 60 per cent. of carbonate of lime.‡

An inspection of the accompanying table,§ which shows the total amount of earthy carbonates in twenty samples from the bottom—in the typical section across the Atlantic (see Fig. 1), will place the leading facts of the case before us in a very instructive manner:—

* For a drawing of Coccosphere see "Depths of the Sea," page 414; for drawings of Rhabdospheres see "Atlantic," vol. i., pp. 221, 222.

† "Atlantic," vol. i., pp. 219 and 228.

‡ "Depths of the Sea," p. 469.

§ Drawn up from data supplied in the appendix to the "Atlantic."

Carbonates; in 20 samples of deposit between the Canaries and the West Indies. See Fig. 1. Page 250.

1.	1,890	fathoms	Gl.	$CaCO_3$.	50·00	$MgCO_3$.	1·32
2.	1,945	„	Gl.	„	64·55	„	1·17
3.	2,740	„	R.	„	56·39	„	0·98
4.	2,950	„	R.	„	4·11	„	1·20
5.	2,750	„	R.	„	16·42	„	2·70
6.	3,150	„	R.	„	3·11	„	1·90
7.	2,720	„	R.	„	13·30	„	1·31
8.	2,575	„	R.	„	51·16	„	1·93
9.	2,025	„	Gl.	„	43·93	„	1·94
10.	1,900	„	Gl.	„	74·50	„	1·27
11.	1,950	„	Gl.	„	79·17	„	1·40
12.	2,325	„	Gl.	„	67·60	„	2·58
13.	2,435	„	R.	„	52·22	„	0·76
14.	2,385	„	R.	„	58·40	„	0·68
15.	2,650	„	R.	„	17·58	„	1·41
16.	3,000	„	R.	„	1·49	„	3·10
17.	2,975	„	R.	„	3·50	„	2·14
18.	3,025	„	R.	„	2·44	„	3·48
19.	1,420	„	Gl.	„	80.69	„	0.68
20.*	450	„	Pt.	„	84.27	„	1.28

Gl. Globigerina-ooze. R. Red clay. Pt. Pteropod-ooze.

In this table only two varieties of deposit are noted, if we except the Pteropod-ooze of the last station, occurring in water of very moderate depth, and close to the shore. On studying the table you will perceive that some portions of the bottom marked "red clay," such for instance as No. 3, at a depth of 2,740 fathoms, contain nearly as much carbonate of lime as the *Globigerina*-ooze to the eastward. Again (presuming that there is no mistake), the station immediately to the westward, practically at the same depth, contains less than 6 per cent. However, you may learn, by comparing the depths with the total amounts of carbonate of lime, that, as a rule, below 2,200 fathoms there is a very material decrease, though affected by some curious irregularities. The purest sample of *Globigerina*-ooze in this traverse contains rather less than 81 per cent. of carbonate of lime; at a less depth, where the pteropod shells are not removed, the percentage is slightly greater.

In his work on the "Atlantic"† Sir Wyville Thomson thus

* Too near the shore to be shown in the section.

† Vol. i., p. 225.

classifies the deposits of the type section (Fig. 1), starting from the Canaries:—

About 80 miles of volcanic mud and sand.—Shore deposits.
„ 350 „ *Globigerina*-ooze.
„ 1,050 „ Red clay.
„ 330 „ *Globigerina*-ooze.
„ 850 „ Red clay.
„ 40 „ *Globigerina*-ooze.

He is careful to point out that these deposits shade into one another, and do not occur in nature, as they are shown for the sake of contrast on maps and diagrams. The *Globigerina*-ooze, for instance, passes gradually into the "red clay" of the greater depths in the form of a deposit to which he gives the name of "grey ooze."

At a depth of 3,150 fathoms the central axis of the eastern basin, or "tea-tray," of the Atlantic is reached. Here the deposit at the bottom is described as "red clay," containing much amorphous matter, and very many small mineral particles, a few broken pieces of pelagic foraminifera and a few manganese grains.* Next comes the Dolphin rise, and with the shallower water the *Globigerina*-ooze is again in the ascendant, though it is easy to perceive from Mr. Murray's report that in this region it is largely contaminated with mineral particles, the colour being often red or rosy, in part from the presence of iron or manganese. This may serve to explain the very high percentages of carbonate of lime in Nos. 13 and 14 (see table of carbonates), marked as "red clay," which, from their chemical composition, should rather be referred to *Globigerina*-ooze.

The axis of the western basin is reached at about 3,000 fathoms, where the carbonates are at a minimum—only 1·5 per cent. of carbonate of lime, but with twice that amount of carbonate of magnesia. It would seem indeed that the agencies which serve to remove carbonate of lime are not unfavourable to the increase of carbonate of magnesia. At this station (No. 16 of the table) a small piece of a shell and a portion of a siliceous spine were the only organic fragments visible, though the mud was full of the cases of a tube-building annelid, formed out of the gritty matter, which occurs sparingly in the clay.

Quitting now the type section along which, in the spirit at least,

* Murray, *vol cit.* p. 476.

we have been walking at the bottom of the sea, let us trace the distribution of *Globigerina*-ooze upon the chart (Fig. 3, p. 257), taking note occasionally of anything remarkable. In those portions of the Atlantic traversed by the Challenger, the deposits classed under this head range in depth from 780 fathoms to 2,675 fathoms. In the Pacific the range is much greater, extending from 275 fathoms to 2,925 fathoms. We can neglect the upward limit, since this is largely affected by the extent to which the deposit may be masked by shore débris. The lower limit is of more importance. I have already pointed out that about 2,200 fathoms may be accepted; yet the limit is extremely capricious, and the cause of the disappearance of the carbonate of lime is still, as far as I know, a matter for conjecture.

By the aid of Mr. Murray's chart, you may perceive those regions where the *Globigerina*-ooze is developed. Here is the traverse we have just made from the Canaries to the West Indies. The great yellow patch between the two reds is the *Globigerina*-ooze of the Dolphin rise, corresponding to the hump at the bottom in Fig. 1.

The north-west basin of the Atlantic is mainly occupied by "red clay," except round Bermuda, where the more purely pelagic matter is masked by coral mud and its concomitants. On the other hand, the shore deposits of the adjacent coasts of North America serve equally to mask the pelagic matter in those depths, where *Globigerina*-ooze might be expected to occur. In addition to this, there is the confusion produced by icebergs, which occasionally drop a few hundred-weight of syenite in a single block, besides other contributions to the deep-sea bottom.*

In fact, though marked as "red clay," there is a fair amount of carbonate of lime in parts of the north-west basin. This is well brought out by reference to the deposit at the very deepest spot yet found in the Atlantic (3,875 fathoms), just north of St. Thomas. It is classed "red clay," but is in reality a bluish grey mud, only red on the top. The chief point of interest however is, that it contains "a good many broken pieces of pelagic foraminifera: pteropods and heteropods; along with a few coccoliths and rhab-

* Sounding of 7th May, 1873, in 1,340 fathoms. Lat. 41° 15′ N., long. 66° 48′ W.—A blue mud composed of:—amorphous matter, an immense number of particles and pebbles, pelagic foraminifera and coccoliths and a few diatoms. Proc. Roy. Soc., vol. xxiv., p. 481.

doliths. The lower layers appear to contain more carbonate of lime than the upper ones." Thus even at the greatest depth known in the Atlantic our old friends have not deserted us, whilst you remember that at far less depths in the typical section (Fig. 1) scarcely a trace of a carbonate-of-lime organism was found. Hence we must conclude *that depth alone, without reference to other considerations, does not always determine the non-appearance of calcareous matter.*

On recrossing the Atlantic, *Globigerina*-ooze again predominates on the plateau whence spring the Azores. In a sounding here at 1,260 fathoms (lat. 38½ N.), besides the usual things, there occurred otoliths of fish, *Cypridina*-valves, urchin-spines, and *Biloculina.* I mention the latter especially, because the remains of this foraminifer take the place of *Globigerina* in the Norwegian Sea at suitable depths and under bottom water colder than ice. This *Biloculina*-ooze, according to Sars, contains a larger proportion of lime than the other.

Next come the shore deposits round the Azores, but when we get clear of these, *Globigerina*-ooze again prevails as far as Madeira, and at depths that surprise us. Here is a sounding in 2,675 fathoms, where the deposit is described as a white *Globigerina*-ooze, "containing much amorphous calcareous matter, many pelagic foraminifera and their broken parts, coccoliths and rhabdoliths, a good many mineral particles, coarse and fine pumice, quartz, mica, a few radiolarians."

Let us now shift the scene to the Pacific, where the depths are greater, and the "red clay" area very extensive, especially towards the north-west. Nevertheless, at a point almost on the meridian of the Sandwich Islands, and a little north of the equator, is a patch of *Globigerina*-ooze, well within the great Radiolarian tract presently to be mentioned. This patch has a maximum depth of 2,925 fathoms, a point at which, on our type section (Fig. 1), almost every trace of lime has vanished. "The carbonate of lime organisms were the most abundant in the lower layers. The upper brown layer had carbonate of lime and siliceous organisms in nearly equal proportions, but more clayey matter and manganese grains than the one underneath."*

* Murray, *loc. cit.*, p. 510.

Thus we perceive that there are deposits containing something like 50 per cent. of carbonate of lime at depths exceeding by hundreds of fathoms those in other parts of the Pacific marked as Red clay. For instance, the S.E. portion of the Pacific is comparatively shallow, though very free from islands, and *Globigerina*-ooze prevails to a considerable extent ; yet an area within this ooze region W.S.W. of Valparaiso, at the moderate depth of 2,270 fathoms, is marked as "red clay," where most of the carbonate of lime has disappeared.

These results make the question of the disappearance of lime very difficult to explain. Should the observations of Herr Tornöe be applicable to all parts of the ocean, the theory of free carbonic acid, never adopted by Mr. Murray, must be abandoned, except in those cases where there may be occasional emanations of carbonic acid through the floor of the ocean itself. There remains the alleged increase in the power for dissolving carbonate of lime possessed by water under greatly augmented pressure, as suggested by Dr. Carpenter from the results of Sorby's observations.* This, and other modes of explanation, have doubtless received the attention of Messrs. Murray and Rénard, whose work, we hope, will shortly be in the hands of the public.

3. *Radiolarian-ooze.*—The siliceous deposits of organic origin are the result of silica-secreting creatures which abound on the surface waters and apparently also in the deepest waters of all the oceans and seas visited by the Challenger, though more numerous in the Pacific than in the Atlantic. Of these, the radiolarians are the most important and the most widely distributed. You may perceive from the drawings of *Dictyopodium* and *Ziphacantha* what sort of fellows are these siliceous rhizopods.† There are also other siliceous organisms of a very microscopic character, originally called Challengerias. The siliceous tests of these various forms are sufficiently abundant in the Pacific to become characteristic of the deep-sea ooze. About half-way between Japan and New Guinea there is a depth of 4,575 fathoms—the deepest Challenger sounding—with a bottom of ooze, containing chiefly the remains of radiolarians, and diatoms, together with Challengerias, and other deep-sea rhizopods ; in this

* "Proc. Roy. Soc.," 1862-3, p. 538.

† For drawings of these forms see "Atlantic," vol. i., pp. 234, 235.

sounding there was a very small amount of amorphous clayey matter, and no carbonate of lime organisms are expressly mentioned. The other areas characterized by radiolarian ooze are not of excessive depth, ranging from 2,000 to 2,250 fathoms.

As regards the *Diatom-ooze*, time will not permit me to do more than indicate the large region in the Indian section of the Southern Ocean, adjoining the shore deposits off the presumed Antarctic continent. Over the area occupied by the siliceous deposit, the higher fauna was found to consist mainly of forms with but little carbonate of lime entering into the composition of their tests, such as very thin-shelled irregular urchins, &c.* Diatoms are most abundant where the specific gravity of the water is comparatively low, but, like the foraminifera and radiolaria, traces of them exist throughout the greater part of the oceanic deposits.

4. There yet remains the important subject of *Red clay*, conspicuously *the* deep-sea deposit; and with this is associated the well-known phenomenon of the manganese nodules, so abundant in certain portions of the ocean, and not altogether absent from our own shallow seas.

In order to give an idea of the composition of Red clay, I append an analysis of a sample from a sounding in 3,150 fathoms, being No. 6 of our type section (Fig. 1 and table, p. 250) in the deepest part of the eastern basin of the Atlantic.

ANALYSIS OF A RED CLAY FROM 3,150 FATHOMS.

(Dried at 110° C.)

Water and organic matter	10·40
Silica	53·30
Alumina	17·40
Ferric oxide...	11·70
Lime, Magnesia } in combination with Silica ...	1·35
Carbonate of lime	3·10
Carbonate of magnesia	1·90
Sulphate of lime	·85
	100·00

In connection with manganese nodules one of the most interest-

* "Atlantic," vol. ii., p. 339.

ing trawls in the Pacific * occurred in 2,335 fathoms, dark chocolate clay forming the upper two inches of the deposit, and light brown clay with many calcareous organisms the lower five inches. The trawl brought up over a bushel of nodules, some without apparent nucleus, some with a hard cherty yellow mineral in the centre. Besides these were over a hundred shark's teeth, and numerous ear bones of cetacea, on all of which much manganese was deposited. With reference to this trawl, Professor Turner remarks† that the remains of at least forty-five whales were fished up on this occasion, but no bone was identified as belonging to the great sperm whale. The spot where all these things were found is within the Red clay area, and their mode of occurrence appears to throw some light upon its history. On this subject one might dilate at considerable length, but it is time that I should move on to another theme, as I feel that if I were once to get well into the Red clay, I should stick there for the rest of the evening.‡

IV. *Life on the Deep-sea Bottom.*—This, indeed, as Mr. Moseley says, must be a very slow affair. In utter darkness, in water almost as cold and sometimes colder than ice, with a pressure amounting to tons on the square inch, the organic functions must be exceedingly mechanical, and sensation reduced to a minimum.

There are just a few points to be considered before we enter into particulars.

1. In deep water there is no plant life, though the absolute limit of vegetation in the sea may not have been determined with precision. A parasitic fungus is not a plant in an economic sense, and therefore the existence of a lowly organized form infesting

* Lat. 33° 29' S., Long. 133° 22' W.

† "Challenger Reports," vol. ii., p. 39, "Bones of Cetacea."

‡ It is also impossible to pay adequate attention to the subject of the manganese nodules, yet a prevalent misapprehension should be removed, viz., that they are composed of nearly pure peroxide of manganese. Some specimens from the Pacific examined by Professor Church contained either a core of Red Clay or fragment of pumice; round these the material was deposited in concentric layers. These layers were found to contain 30 per cent. of manganese dioxide, the remainder consisting chiefly of water, ferric oxide, and silica. Church, in "Min. Mag." vol. i., p. 50.

Mr. Buchanan states that the manganese occurs wholly as peroxide, which amounts to about 35 per cent., with some 25 per cent. of ferric oxide, from 15·20 per cent. of insoluble residue, and 8·10 per cent. of water, with variable proportions of alumina and soda. Cobalt, with copper and a little nickel, is present in all of them. "Proc. Roy. Soc.," Edin.

corals—even at 1,000 fathoms—constitutes no exception to the rule. This absence of vegetation bears on the food question: whence do the deep-sea animals obtain their supplies? There used to be a theory which regarded the waters of the ocean as a sort of *soupe maigre*, enriched by lumps of protoplasm. Those were the days of *Bathybius* and the "Urschleim." It seems now to be held that the ultimate sources of food are derived entirely from above. Mr. Moseley calculated that it would take a dead Salpa four days to fall through 2,000 fathoms of water.

If diatoms, coccospheres, and rhabdospheres are so far vegetables as to have the power of decomposing inorganic substances, they must also contribute to set the vital circle in motion. Star-fish, holothurids, &c., doubtless fill their digestive sacks with these, as well as with foraminifera and radiolarians. Thomson gives an account of a holothurid so transparent that when the body cavity was distended with diatom-ooze the animal looked like a thin, transparent bag filled with it.*

2. Life only occurs within moderate distances of the surface, and on the bottom. The intermediate depths, which, according to Sir Wyville Thomson, are the most stale, probably contain hardly any. A. Agassiz considers that certain experiments "appear to prove that the surface fauna of the sea is really limited to a comparatively narrow belt in depth, and that there is no intermediate belt, so to speak, of animal life between those living on the bottom or close to it and the surface pelagic fauna."† It amounts to this, therefore, that, in the ocean, life is restricted to waters near the top, and at or near the bottom.

3. What do we mean by deep-sea now-a-days? Three hundred fathoms was deep water in Forbes' time, and this depth may now, I suppose, be roughly accepted as the upper limit of the deep-sea. A. Agassiz concluded recently, according to Mr. Moseley, that the fauna extending from the shore to 150 fathoms should be termed the littoral fauna; "whilst from the hundred fathom line to the four hundred fathom line extend species which are neither littoral,

* "Atlantic," vol. ii., p. 339. It becomes a singular question how far the juices of such creatures succeed in dissolving silica, which they do not secrete. Fancy an animal having *Dictyopodium* for his dinner and *Ziphacantha* for his dessert.

Quoted by Dr. Gwyn Jeffreys, *loc cit*, p. 182.

nor have the wide geographical distribution belonging to forms found below that depth." Sir Wyville Thomson has told us very lately * that the "abyssal" fauna attains its greatest development in a zone of depth between 600 and 1,200 fathoms. Below that depth, though the character of the fauna may remain the same, yet its abundance is materially diminished.

These views do not seem quite to coincide, but perhaps we may roughly gather, (1) that there is a *littoral fauna*, an *intermediate fauna*, and a *deep-sea fauna*, (2) that the latter extends from 400 fathoms to any known depth, but attains its maximum development between 600 and 1,200 fathoms, whilst below 2,000 fathoms, especially on red clay bottoms, life is very scarce.

Here is a picture, painted by Prof. G. D. Sars† of marine life at depths from 400 to 900 fathoms in the cold water area between Norway and Iceland, where, contrary to expectation, the prevailing low temperature is no hindrance to the development of animal life. "Forests, of a peculiar group of sponges (Cladorhiza) with tree-like branches, deck the bottom for long distances. Various crustacea, amongst them the wonderful object, *Arcturus Baffini*,‡ known from the polar sea, and slow-moving Pycnogonida, some of colossal size, creep along between these sponge branches, and suck out their organic juices; whilst a whole world of more delicate Polyzoa and Hydrozoa find their abode on the sponges that are dead." The writer then goes on to describe the submarine population in the open spaces between the sponge forests. He speaks of the sea stars (*Astropecten*) and ophiurids, and here again of the swarms of crustaceans. Above all predominate the Umbellularias, "with their delicate straight stems and elegantly curved crowns set full of fringes of polyps." In default of sunlight this glacial aquarium is illuminated, if not warmed, by the phosphorescence of the animals themselves, and especially of *Umbellularia*, which we can almost imagine as playing the part of a submarine gas-lamp, or electric light, if you will, to its more lowly companions.

The Norwegians called this the region of the *Umbellularia*. Upon

* "Challenger Reports." General introduction.

† Norwegian North Sea Expedition—"Nature," March, 1877.

‡ For drawing see "Depths of the Sea," p. 128.

the wall is a drawing of *Umbellularia greenlandica.** The group of which this genus is a member extends to very considerable depths, some species occurring below 2,000 fathoms. It belongs to the division of Alcyonarian polyps called Pennatulids. These, for the most part, says Dr. Kölliker, are very shallow water forms ; moreover, they are more complex in organization than their deep-sea relatives.

Dr. Kölliker further observes that this peculiarity holds good with regard to the other invertebrate groups, viz., that the deep water organisms are the more simply constructed relatives of shallow water forms—*i.e.*, one might almost say, of forms which, under the stimulus of light and more food, have lived faster and become more highly developed. In this way also he arrives at the conclusion that these simple forms are probably the oldest and may be regarded as the last remnants of an almost extinct primary creation.

I may mention that *Umbellularia* was once regarded as the living representative of the "lily" encrinite. † But the latter has far nearer relatives ; some of whom we will now proceed to consider.

The Crinoidea form an interesting group in the deep-sea fauna —interesting from its beauty, its comparative rarity, and above all, to palæontologists, from the fact that it has seen better days. I should note, however, at the outset that, though the stalked crinoids occur in deep water, they are also found according to Moseley, in a depth of 40 fathoms. A representative of the genus *Pentacrinus*,‡ of which there is a drawing on the wall, was brought from the West Indies more than a century ago. The first deep-sea Pentacrinite was, I think, dredged by Dr. Gwyn Jeffreys at a depth of 1,095 fathoms off the coast of Portugal, and named by him after Wyville Thomson.

A more singular group of living crinoids—wholly unknown before the days of deep-sea investigation—is that referred by

* For drawing see "Atlantic," vol. i., p. 150. Dr. Kölliker has described several new species, one of which—a very elegant form—he calls *Umbellula Huxleyi*. "Challenger Reports," Zoology, vol. i.

† "Atlantic," vol. i, p. 151.

‡ *Pentacrinus asteria*, L. For drawing see "Depths of the Sea," p. 436.

Thomson to the Apiocrinidæ, of which the well-known pear-encrinite of the Bradford Clay may be taken as the type. Of these new crinoids, *Rhizocrinus loffotensis*, Sars, first dredged off Norway was early found in the British seas at a depth of 530 fathoms (temp. 43·5 F.), and has since been taken elsewhere. There seems to be little doubt, says Sir Wyville Thomson, that *Rhizocrinus* finds its nearest known ally in *Bourgueticrinus*, a very aberrant form from the chalk.*

There is another of these forms, viz., *Bathycrinus*, which is also referred to the Apiocrinidæ on the grounds that "the lower portion of the head consists of a gradually expanding funnel-shaped piece, which seems to be composed of coalesced upper stem-joints."†

A great haul of this sort of crinoids was made by the Challenger, between the coast of Africa and St. Paul's rocks, in 1,850 fathoms (35° F.) on a bottom of *Globigerina*-ooze. Besides a very handsome new *Bathycrinus*, they took a form to which the generic name of *Hyocrinus* was given. This has a striking, though, we are told, superficial resemblance to certain palæozoic genera, one of which, *Periechocrinus*, is placed alongside in the drawing for comparison.‡

Altogether there have been found, according to Sir Wyville Thomson's communication to the Linnæan Society,§ five living species belonging to three genera referable to the Apiocrinidæ; but it remains for the morphologist to determine how far the solid structure of the Jurassic Apiocrinids resembles that of these recent forms.

The Star-fishes and Ophiurids of the deep-sea are also interesting from their partial resemblance to ancient forms. This is especially seen in *Astrogonium*, *Archaster*, *Astropecten*, and their allies.‖ At the same time, it must be remembered that there are many genera belonging to other groups which also inhabit the

* For drawing of *Rhizocrinus loffotensis*, Sars, see "Depths of the Sea," p. 451.

† "Depths of the Sea," p. 450; and figure of *Bathycrinus gracilis*, W. T., p. 453.

‡ For drawings of *Hyocrinus*, see "Atlantic," vol. ii., pp. 96, 97.

§ "Journal—Zoology," vol. xiii., p. 47.

‖ "Depths of the Sea," p. 455.

deep-sea. Here is a drawing of *Archaster bifrons*,[*] showing the tesselated mailing on the disk and massive marginal plates. To this group belongs the well-known *Astropecten rectus*, a cast of which, from the Kelloway Rock of Yorkshire, is exhibited by Dr. Woodward.

Again, if we take the Urchins (Echinoidea) we trace a likeness to some long-lost friends in several of the deep-sea forms. Here is *Salenia*, for instance, not heard of on this side of the equator[†] since the days of the chalk. A specimen of one of these prizes from the deep is kindly lent for exhibition by the President of the Geological Society.

The chalk genus *Ananchytes* would also seem to have its representatives in the deep waters of the modern ocean. This may be especially noted in an irregular urchin, called *Calymne relicta*, W. T., trawled from 2,650 fathoms off Red clay, between Halifax and Bermuda.[‡] It is amongst these irregular urchins that the relation between the modern "abyssal" fauna and the fauna of the later mesozoic beds is most marked; and it is right to bear in mind that the genera allied to *Infulaster* and *Micraster* are more abundant and bigger in the Southern Ocean than elsewhere.[§]

But the most wonderful of all these Urchins, allied to Cretaceous forms, is *Asthenosoma*, Grube. The celebrated *Calveria hystrix* belongs to this genus, and it seems almost a pity that the name of the captain should no longer accompany that of the ship (the Porcupine) in connection with this very interesting species. This Urchin[‖] has a flexible test, reversed imbrication, and other peculiarities, which closely ally it with the once puzzling genus *Echinothuria*. An allied genus, *Phormosoma*, has been found in 1,525 fathoms off Cape St. Vincent, and in 400 fathoms off the east coast of Australia.

In connection with this subject, I should remind you that Mr.

* For figure see "Depths of the Sea," p. 132.

† Professor Tate found a *Salenia* in the Middle Tertiaries of Australia. "Q. J. G. S.," vol. xxxiii., p. 256.

‡ "Atlantic," vol. i., p. 396.

§ "Atlantic," ii., 332.

‖ For figure of *Asthenosoma* (*Calveria*) *hystrix*, see "Depths of the Sea," p. 156.

Walter Keeping has lately described from the Coral Rag of Calne an urchin which he calls *Pelanechinus*, and which he believes to have had its test flexible, though not to such an extent as in *Asthenosoma*.* Similar forms have been traced back as far as the Devonian.

The number of Corals dredged by the Challenger in deep water was comparatively small; "they were mostly simple and solitary, and the greater number belonged to the Turbinolidæ; many of the genera pass back to tertiary, and a few to mesozoic times."† *Caryophyllia borealis* is well known off our own coasts, and the only species, higher than Protozoan, that is common to modern deep-seas and the chalk, would seem to be *C. cylindracea*, Reuss. Prof. Duncan, who was the first to point this out, remarks, at the same time, on the very persistent character and less variable nature of the corals of the deep-sea fauna.‡

Bathyactis symmetrica, Pourtalès, one of the Fungidæ, has probably, the widest range of anything living, as it literally extends all over the world, and through all depths from 30 to 2,900 fathoms.§ In certain places off the British coasts, at depths from 300 to 600 fathoms, the handsome branching coral, *Lophohelia prolifera*, Pallas, forms stony copses covering the bottom for many miles.‖

Mr. Moseley considers that the deep-sea forms of the true corals are not, as a whole, of greater geological antiquity than shallow water forms. Many of the genera have a considerable range in depth, but those which attain extreme depths are *Deltocyathus*, *Flabellum*, and *Bathyactis*. The annexed abstract from the very complete table given by Mr. Moseley¶ will serve to show the range in depth and time of a few of the genera more especially interesting to the student of palæontology.

* "Q. J. G. S.," vol. 34, p. 924, *Pelanechinus corallinus* (Wright), Keeping—was originally described by Dr. Wright, in 1855, as a *Hemipedina*, from a fragment said to have been obtained in the Coralline Oolite of Malton.

† "Atlantic," ii., p. 346.

‡ "Q. J. G. S.," vol. xxvii., p. 436.

§ For figure of *Fungia symmetrica*, see "Atlantic," vol. ii., p. 149.

‖ "Depths of the Sea," p. 168.

¶ "Challenger Reports," Zoology, vol. ii., p. 132.

	Depth.	Age.	
TURBINOLIDÆ.			
Caryophyllia	shallow water—1500 fms.	Ter.	Sec.
Deltocyathus	150 fms. —2250 fms.	Ter.	
Trochocyathus	100 fms. — 750 fms.	Ter.	Sec.
Sphenotrochus	shallow water— 150 fms.	Ter.	
Flabellum	shallow water—1500 fms.	Ter.	
Parasmilia	50 fms. — 300 fms.		Sec.
OCULINIDÆ.			
Lophohelia	100 fms. —1000 fms.	Ter.	Sec.
ASTRÆIDÆ.			
Astræa	shallow water— 150 fms.	Ter.	Sec.
Cladocora	shallow water— 50 fms.	Ter.	Sec.
FUNGIDÆ.			
Bathyactis	50 fms. —3000 fms.		
EUPSAMMIDÆ.			
Balanophyllia	shallow water— 400 fms.	Ter.	
Dendrophyllia	50 fms. — 750 fms.	Ter.	
Stephanophyllia	100 fms.	Ter.	Sec.

We have a representative of the hydroid corals in the very elegant *Cryptohelia pudica*, Miln. Ed., which occurs all over the world at depths from 350 to 1,500 fathoms. The drawing represents the common skeleton of a highly complex colony.*

The importance of the Sponges is perhaps more considerable. To-night we must confine our attention to the Hexactinellidæ—a group especially dear to the geologist. There are several genera which affect deep water, but I will only mention three.

Off the north-west coast of Scotland *Holtenia*, the sea-nest sponge of the Portuguese shark fishers, is particularly abundant on a bluish-grey calcareous mud containing some sand and a considerable admixture of *Globigerinæ*, and which extends from off the Butt of the Lews to Gibraltar. Along with this is *Hyalonema*, the celebrated glass-rope sponge of the Japanese, which has been the means of deceiving so many collectors. The researches of Professor Sollas and others have made us acquainted with the exquisite internal structure of many of the Hexactinellids, but

* For figure, see "Atlantic," vol. i., p. 272. "It is true that corals, which come within Milne-Edwards' definition of the Rugosa, occur in deep water, but that group needs great modification, and the structural difference between the deep-sea forms and ordinary Caryophyllias is probably of comparatively little zoological importance." Moseley, "Nature," Ap. 15, 1880.

perhaps the most striking of all these pieces of siliceous network is *Euplectella*. I would especially draw attention to *Euplectella suberea*,* W. T., a new hexactinellid obtained in 1,090 fathoms off Cape St. Vincent. There is such a strong general resemblance between this form and *Ventriculites simplex*, T. Smith, of the chalk, that I have had drawings of the two placed side by side in order that you may note their resemblances and their differences.

Before quitting the subject of the sponges I would also remind you that the Hexactinellidæ, though undoubtedly a deep-water group in the present day, have their comparatively shallow water representative in the well-known Venus' Flower-basket (*Eupl. aspergillum*), which occurs as high up as 90 fathoms, in water having a temperature of 70° F., on a soft blue mud at Zebu, in the Philippine Islands.

It would, of course, be utterly hopeless to go through all the classes. There are just two more which have a claim to some notice. We cannot altogether slight the Crustacea, since these are so extremely characteristic of some parts of the deep-sea, and especially of the cold areas, where they frequently attain to a very great size. The macrurous decapods are particularly numerous, whilst the brachyurous decapods appear to be confined almost entirely to comparatively shallow water. There is a large family, having a strong general resemblance to the fossil genus *Eryon*.†

It is well known that in the deep-sea animals, the eyes are frequently atrophied or altogether absent; but in some cases the eyes are very large and clear. This is well shown in the crustacea, and is a good illustration of the opposite action of the same cause, showing how extremes may meet. The following drawings are exhibited in this connection :—

Bathynomus giganteus, Alp. Miln. Ed., one of the largest isopods, with huge facetted eyes, dredged in 1878 from 900 fathoms.

Thaumops pellucida, Von W. S., 84 millimetres long, an amphi-

* For figure of *Euplectella suberea*, see "Atlantic," vol. i., p. 139. For figure of *Ventriculites simplex*, see "Depths of the Sea," p. 483.

† A drawing of a specimen from the Lias of Barrow-on-Soar was exhibited. See also "Geol. Mag.," Dec., 1881, p. 349.

pod trawled in 1873 from 1,090 fathoms off Cape St. Vincent. This has large compound eyes.*

Polycheles (*Willemösia*) *crucifer*, W. T., a macrurous decapod without eyes, dredged in 1873 from 1,000 fathoms off the West Indies. The same genus occurs abundantly in 320 fathoms, near the Fiji Islands, along with the pearly *Nautilus*.†

The Brachiopoda also have especial claims on our notice. This class extends from 5 to 2,900 fathoms, but considerably more than half the species known to exist occur in depths of less than 150 fathoms. *Discina atlantica*, a shell about three millimetres in length, ranges from 600 to 2,425 fathoms, whilst *Lingula* ranges from a depth of a few inches to no more than 60 fathoms. A species of *Terebratula*, having a range from 1,035 to 2,900 fathoms, has been found at six stations on various kinds of ground; it is a good size, outwardly like a *Waldheimia*, and, according to Mr. Davidson, very much resembles a fossil from the Kimmeridge Clay of Switzerland. There is a *Terebratulina* occurring in 390 fathoms, off St. Thomas Island, which the same authority declares to be the finest species of the subgenus, recent or fossil.‡

I am trying to get on, but the Mollusca will have a word, especially the Gasteropoda and Lamellibranchiata. We have the authority of Sir Wyville Thomson that they do not enter largely into the fauna of the deep-sea, and this must be accepted, more especially as regards the vast extent of submarine flats away from the continental margins. In these great plains the Mollusca are for the most part small and stunted; yet nearer shore, even in tolerably deep water, they are sufficiently numerous. A proof of this we have in Dr. Gwyn Jeffreys' celebrated haul off the coast of Portugal in 994 fathoms, when he obtained 185 species of Mollusca (including Pteropods), of which 23 were Pliocene Gasteropods.§ Such an assemblage may have been accidental. Another

* For figure of *Th. pellucida*, see "Phil. Trans.," 1873, pl. 49.

Dr. Woodward informs me that several of these large-eyed amphipods are in the habit of taking up their quarters in the stomachs of Medusæ and pelagic Tunicata. It is a somewhat curious coincidence that these Medusæ are highly phosphorescent, so that the amphipods obtain both light and lodgings for nothing.

† Moseley, "Notes by a Naturalist," p. 297. For figure of *P. crucifer*, see "Atlantic," vol. i., p. 256.

‡ See "Challenger Reports," Zoology, vol. i.

§ "Depths of the Sea," p. 183.

remarkable exception to the rule is the case of a volute allied to *Cymbium*, 6¾in. long and 4in. broad, dredged in 1,600 fathoms off the Crozet Islands.*

Conclusion.—In thus giving a partial and imperfect sketch of the deep-sea fauna, with more especial reference to those groups likely to be of interest to the geologist, there is a possibility of producing an exaggerated impression as to the relative importance of these groups. If the discovery of a few survivors of classes which have been more numerous in former times is to be held conclusive, the stalked Crinoids might claim that they were still living in Jurassic or even older periods. In opposition to them the Ventriculite-like Hexactinellids and the Urchins which resemble the Salenias, the Echinothurias, and the Ananchytidæ of the chalk, would claim that they were living in the Cretaceous period.

It was very natural in the early days of deep-sea dredging, when several of the forms long supposed to be lost kept turning up, to attach an undue importance to their occurrence. The discovery at the same time that there are deposits forming in the Atlantic which have some resemblance to chalk gave additional weight to the zoological evidence in favour of the Cretaceous period. The time for wholly removing what appears to be a misconception on the part of some geologists has not, perhaps, yet arrived. We await the fuller reports of Sir Wyville Thomson and Mr. Murray, though it is pretty clear what are now the opinions of those gentlemen. Sir Wyville Thomson, writing a year ago with reference to the views of Mr. Murray and himself, observes :—"(1) That the chalk of the Cretaceous period was not laid down in what we now consider deep water, and that its fauna, consisting mainly of shallow water forms, merely touches the upper limit of the abyssal fauna. (2) That no beds exist in the series of known sedimentary rocks which correspond in composition and in structure with the beds now in process of formation in the abyssal sea."† This is a pretty strong recantation on the part of the author of the "Continuity of the Chalk," but Sir Wyville has seen a little more of the world since those days.

Another point of considerable importance to geologists should also be urged. Since some species and many genera range at pre-

* Gwyn Jeffreys, *loc. cit.*, p. 180.

† "Nature," Nov. 11, 1880.

[redacted]

sent almost from the shore to vast depths, many forms now restricted to deep water may formerly have lived in less depths, and most probably did so. Hence no absolute conclusions of any value can be drawn as to the depths at which a deposit was formed "until the reign of reef coral and plant life is reached."* For instance, it would be useless to urge that *Pentacrinus* is necessarily a deep-sea form, and hence that the Lias was deposited in deep water, for if *Pentacrinus* now ranges from abyssal depths up to 40 fathoms, and from cold to very warm water, its range as to temperature and depth in the past can in no wise be limited.

At first sight such a conclusion is rather discouraging, but we may fairly believe that the general facies of a fossil fauna will still have its bathymetrical value, though no one would be justified in appealing to the evidence of a limited number of forms. In this way a truly littoral fauna will always carry its mark with it, and the original divisions of Forbes for water of moderate depth will probably be true both for the past and the present.

It follows, therefore, that the power of adaptation which probably all groups of invertebrate animals possess, whereby many modern shore genera, and even species, are enabled to exist at great depths, renders it difficult to use the zoological evidence in deep-sea investigations for estimating the depth at which a given formation may have been laid down. Similarly the lithologists have, as you know, arrived at the conclusion that the beds now forming under the deep-sea correspond to none of the known sedimentary rocks.

But if the immediate advantages to geological science are, perhaps, not so great as was at one time hoped and believed; if hardly a single *species* has yet been found, excluding the Protozoa, of more than Pliocene age, notwithstanding the representatives of old and curious groups; if not a single animal has yet been brought to light which can supply the missing link between any of the great zoological classes; † and if modern deep-sea deposits are unlike anything in the known sedimentary rocks, are we to suppose that deep-sea investigation has no geological import? Certainly not.

Besides the hydrographical, physical, and chemical results which

* Moseley, in "Nature," *loc. cit.*

† Moseley, *loc. cit.*, p. 571.

have been added to the store of human knowledge, an acquaintance with the deep-sea fauna will always have its value. That fauna has a certain relation to the existing shore fauna, as previously noted, but there are other elements of older date, as we have also seen. Why should it not be regarded as a vast colony or back settlement which has from time to time throughout the geological ages received the surplus population of the happier shallows—those shallows where sea and air unite, under the stimulating effects of warmth and the solar rays, in offering a congenial cradle to life? This would at once explain its genetic relations to the past and to the present, without the necessity for supposing that existing deep-sea conditions are representative of any particular epoch of the earth's history.

In thus changing or enlarging their habitat, some groups—the macrurous decapods, for instance—rather flourish in the deep-sea, whilst their more sagacious relatives, the brachyura, take care to remain above. It is evident from the monotonous character of the deep-sea fauna generally, and from the comparative simplicity of several of its groups, that uniformity of conditions, a constant low temperature, and absence of solar light has, on the whole, a conservative effect on the tendencies to structural change inherent in all organisms. We thus have a zoological assemblage to which more than one age of the earth has contributed its quota, an assemblage hitherto safe in the cold, dark depths of the once mysterious ocean, but which the persevering curiosity of man is by degrees dragging forth from its hiding-place.

ORDINARY MEETING.

DECEMBER 2, 1881.

W. H. HUDLESTON, Esq., M.A., F.G.S., President, in the Chair.

The list of donations to the Library since the last meeting was read, and the thanks of the Association returned to the donors.

The following were elected Members of the Association :—

Jer. Ryan, Esq., Assoc. Inst. C.E.; Richard Phipps, Esq.; Thomas Hart, Esq., F.G.S.; Charles Christopherson, Esq.; W. Kinsey Dover, Esq., F.G.S.; H. J. Jenkinson, Esq., F.R.G.S.; Dr. Rumney; J. Postlethwaite, Esq.; Miss L. H. King; F. J. Hanbury, Esq.

The following paper was then read :—

ON SOME RECENT RESEARCHES AMONG LOWER PALÆOZOIC ROCKS IN THE BRITISH ISLES.

BY HENRY HICKS, M.D., F.G.S.

INTRODUCTION.

In the paper which I had the pleasure of reading at the meeting of the Geologists' Association, in December last year, I endeavoured to give a brief statement of the chief results of the researches which had been carried on among the pre-Cambrian rocks in the British Isles during the preceding twenty years. In the present paper I hope to give an account of some of the most important results derived from similar researches among the Lower Palæozoic Rocks during the same period. Twenty years ago it was universally believed that in the areas in England and Wales, where the Lower Palæozoic Rocks were known to be best developed, and where they had been chiefly examined, there was no evidence of a true base line, or of the floor upon which these rocks had been deposited.

As explained in my former paper, we are now able to point out many areas where fragments of the old floor may be seen, and to recognise the earliest of the palæozoic sediments resting upon it. It is highly satisfactory to start thus from a good base line, and to have a tolerably clear idea of what the thicknesses of these earlier sediments must be in areas where previously this could only have been arrived at through vague suppositions.

Moreover, these discoveries have enabled us to realize, to some extent, the physical conditions which prevailed at the time of deposition in those areas.

The Lower Palæozoic Rocks of Britain are best divided into three great groups or systems, and to these the names, in ascending order, of Cambrian, Ordovian, and Silurian, have been given.

Lower Cambrian.

The term Cambrian was first used by Prof. Sedgwick, and it was intended by him to include the Harlech and Llanberis groups, with the succeeding rocks, to the top of the Bala series. At present, however, except by the Cambridge school, it is generally used in a more limited sense. The late Mr. Salter and myself, years ago, saw the necessity of restricting the term to the rocks containing the so-called primordial faunas. This view was adopted also by the late Sir Chas. Lyell, and it seems now to meet with very general support from those who have paid much attention to these rocks in this country and abroad.

The Cambrian in this paper, therefore, has its upper limit defined by the top of the Tremadoc rocks. There is really no stratigraphical break at this point. Still the fossil groups above and below are so distinct, on the whole, that the boundary line falls naturally there.

Recently I have divided the Lower Cambrian into three groups, under the names in ascending order of Caerfai, Solva, and Menevian.* Wherever these rocks are found in this country, in contact with any of the pre-Cambrian groups, they are seen to rest unconformably upon them. They usually contain fragments of the older rocks in abundance, and evidences that they must have been built up chiefly from the denudation of the older rocks are everywhere apparent. At the base conglomerates are always seen. In North and South Wales the fragments in the conglomerates are usually well-rounded pebbles, and these are for the most part, identical with the rocks upon which they repose. Angular and subangular fragments also occasionally occur. In the north-west of Scotland, however, huge angular masses are much more frequently found in them, and in some places they have more of the characters of breccias, than of marine conglomerates. In

* "Pop. Science Review," Oct., 1881. See also Etheridge, "Presidential Address," Quart. Journ. Geol. Soc., May, 1881; and Lapworth, "Geol. Mag.," July, 1881.

previous papers* I have endeavoured, from the evidence derived from the conglomerates, and from the appearance of the old floor on which they rest, to point out some of the physical features of the old pre-Cambrian land. The angular character of many of the fragments, and the smoothed and evenly undulating surfaces exhibited by the floor, lead to the conclusion that, to some extent at least, they were due to ice action. The pre-Cambrian continent was, evidently, studded not only with volcanic mountains, but also with high ridges and plateaux in northern latitudes. Therefore we are led to believe that the latter, at least, were covered with ice and snow in their higher parts, and that the plains and valleys had much loose material strewn over them. The thick beds of conglomerate everywhere at the base, and the frequent alternations of conglomerates, grits, and sandstones, throughout the lower several thousands of feet of the Cambrian rocks, seem to prove that an abundance of loose material must have been near and ready at hand to be easily denuded off as each part of the old land became submerged. Marine action on the hard metamorphic rocks could scarcely have produced so much sediment. Moreover, the enormous thickness found, with scarcely a trace of any beds formed by marine life at this period, indicates that some additional force must have been at work. In some places also the sediments were deposited so rapidly as to keep pace with a depression of several thousands of feet. I am inclined to believe that the British area formed a portion only of the western margin of a great continent at this time, and that some of this material might primarily have been derived from a considerable distance. In an east and west line the continent would extend from at least the 100-fathom line beyond the British Isles to Asia. The higher land was probably towards the north-east, with a general trend towards the south-west. The surface appears to have been of an undulating character, with the higher ranges running in the direction of east-north-east and west-south-west. These Lower Cambrian rocks, being the earliest sediments, would vary considerably in thickness in different areas. In Scotland, where they rest almost horizontally on the old floor, they are seen to fill up the unevennesses of the surface, and to attain a greater or less thickness in proportion to their extent. In Wales they have been more disturbed, and are usually tilted up at a tolerably high angle.

* "Quart. Journ. Geol. Soc.," 1875, and "Geol. Mag.," 1866.

Here, however, the evidences of their having varied with the unevennesses of the surface are also more or less apparent. Whatever the history of the earlier epochs may have been, it is clear that new physical conditions, on a large scale, were now prevailing over the British Isles. At this period also the history of life, as far as the present reliable evidence is forthcoming, commences. The very earliest of these sediments contain evidences of marine life. Annelid tracts and burrows are found abundantly in the sandstones, that rest immediately upon the conglomerates, and almost as early we find Brachiopods and Crustacea. All are marine forms, and they must have arrived on the scene as soon as the waters encroached on the old land. The question naturally occurs, where did they come from? We have, so far, no evidence of their presence or of that of allied types in any of the pre-Cambrian rocks. They certainly did not attain to their state of perfection by any instantaneous process; therefore their ancestors ought to be found somewhere. Now if my suppositions are correct that the waters at this time encroached from a western direction, it is easy to suppose that in the great Atlantic basin—then, as now, probably, one of the great oceanic basins—they had gradually attained, through numerous stages, the state of development shown. As none of the earlier sediments in this basin can be examined, its life succession is completely hidden from us. We are, therefore, justified, I think, in believing that could we but get at these sediments, we could there trace the history of life to far earlier times. The Eozoon is still regarded of so doubtful a nature that I do not call special attention to it. Moreover, it does not help us in arriving at the character of the immediate ancestors of our Cambrian fauna, with which we have now to deal. It is not at all improbable that ere long we may find some traces of life in the Pebidian rocks—the least altered of the pre-Cambrian groups—for I have frequently noticed markings in the slates of that group which call to mind very strongly some of the annelid markings of the Cambrian rocks. The land, which was being gradually encroached upon, would probably also be clothed with vegetation of some kind though, in the Cambrian rocks, we have but very little evidence of its nature. When at St. David's last summer I spent a considerable time in searching the conglomerates and the immediately overlying sandstones for traces of land plants, and I was

not altogether unsuccessful, for in the sandstones I detected bits of carbonaceous matter which, I think, must have been derived primarily from land plants. There was no structure visible, however, and for the present I prefer to speak of its origin with some doubt. No chapter in physical geology and geography has interested me so much of late years as that which pertains to this period in the history of the globe, and I think I may venture to claim that my paper on the "Physical Conditions under which the Cambrian and Lower Silurian Rocks were Probably Deposited Over the European Area," in the "Quart. Journal Geol. Soc.," Nov., 1875, was instrumental in bringing this question more prominently before the geological world than it had previously been. More recently Prof. Geikie, in "Nature," Aug. 26th, 1880, and Prof. Hull, at the Brit. Assoc., 1881, have put forward views almost identical with those given in my paper in 1875.* The former says,† "I think we have, in the meantime, grounds for concluding that in the north-west of Scotland there is still traceable a fragment of the earliest known land-surface of Europe, that this primeval country had a smooth, undulating aspect, not unlike that of the west of Sutherland at the present time, that it contained rock hollows, some of them filled with water, that into these hollows piles of coarse angular detritus were thrust, that around and beneath the tracts, where this detritus accumulated the gneiss was worn into dome-shaped forms, strongly suggestive of the operation of land-ice, and that though the ice of the last glacial period undoubtedly ground down the platform of gneiss, bared as it was of the overlying formations, it found a surface already worn into approximately the same forms as those which it presents to-day."

Prof. Hull, in his paper,‡ calls attention to the differences in mineral character between the Cambrian of the north-west coast of Scotland and that in Wales and in Shropshire, and he believes that these differences "were due to deposition in distinct basins lying on either side of an archæan ridge of crystalline rocks which ranged probably from Scandinavia, through the Central Highlands of Scotland, and, included the north and west of Ireland, with the counties of Donegal, Derry, Mayo, Sligo, and Galway, in

* See also a paper by me in "Geol. Mag.," April, May, and June, 1876.

† "Nature," Aug., 1880, p. 403.

‡ See abstract in "Geol. Mag.," Nov., 1881.

all of which the Cambrian beds were absent, so that the Lower Silurian repose directly and unconformably on the crystalline rocks of Laurentian age."

The differences in mineral character between the Cambrian rocks in Scotland and those in Wales are not so important as supposed by Prof. Hull, for, as I have repeatedly shown, they depend to a great extent, especially in the lower beds, on the nature of the underlying rocks. Where they rest on schists the fragments are mainly derived from these; and where, again, as in many parts of Carnarvonshire, they rest on quartz-felsites, the greater part consists of rolled fragments of those rocks. In Scotland it is the same. At Gaerloch, where they rest on greenish and micaceous schists, I noticed that the masses in the conglomerates were mainly portions of these schists. In other areas fragments of gneiss rocks prevail. This shows clearly that we have at these places the old shore lines. I maintained, in a former paper, that there must have been wide depressions at the time the Lower Cambrian rocks were deposited over the European area in lines more or less in the direction of north-east to south-west, and it appears now that there is distinct evidence of these in Scotland, as also in England and Wales, in addition to minor irregular basins.

In Prof. Ramsay's "Memoir on the Geology of North Wales," published in 1866, p. 7, he says that the "Cambrian Rocks of the Longmynd were in the 'Silurian System,' shown by Sir Roderick Murchison to underlie the whole of the Silurian strata, and when in 1846 and 1848 the Geological Survey mapped the equivalent rocks in Merionethshire and Caernarvonshire, they naturally adopted this name for these deposits. Stratigraphically they occupy the same position, and lithologically they much resemble each other." Again, in referring to the Pembrokeshire rocks, he says, "In the same year (1841) at St. David's, I traced a provisional line between the black and the purple slates, and this was afterwards adopted as the line between the Silurian and Cambrian strata." The Cambrian of the Geological Survey therefore is nearly the equivalent to that included in this paper as Lower Cambrian. There is one very important group, however, the "Menevian," unknown at the time the lines of division were drawn by Prof. Ramsay at St. David's, but now known to lie chiefly above that line, which, both on stratigraphical and fossil evidence, must be included with the lower rocks. With this cor-

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rection, I see no reason to doubt that the rocks called Cambrian by the Geological Survey are more or less contemporaneous deposits in the several areas in which they have been so marked by them.

In each of the areas they have many important mineral characters in common, and in some, as in the St. David's, Harlech, and Llanberis areas, where they rest upon pre-Cambrian rocks, and are succeeded by easily recognised fossiliferous series, they do not appear to have varied much in their thickness, certainly not more than might be expected in subsiding areas with moderately undulating surfaces.

The Lower Cambrian (Cambrian of the Survey) in Wales has an average thickness of from 5,000 to 8,000ft. It contains several distinct faunas, which have been discovered within comparatively recent years. In these faunas I found, in addition to the Annelids, discovered many years ago by Mr. Salter in the Longmynd rocks, and afterwards by Dr. Kinahan in the Bray Head rocks in Ireland, some Sponges, Brachiopods, Trilobites, Ostracods, Pteropods, and Cystids. The genus *Paradoxides*, which contains the largest trilobites known, appears in this country to be restricted to the Lower Cambrian groups. The majority of the rocks in the lower groups are very barren in organic remains, one thin band only perhaps containing evidence of their presence in over 1,000ft. of beds. The upper group, the Menevian, on the other hand, is highly fossiliferous throughout, with, however, some well-marked zones. Over 50 new species have been found in this group by the late Mr. Salter, Mr. Homfray, and myself in North and South Wales.

With the exception of two or three species, these were first discovered at St. David's, and subsequently around the Merionethshire Anticlinal, where the zones occur exactly as at St. David's. The Menevian rocks there lie upon exactly similar rocks, called the Harlech group, to those I have called at St. David's the Solva group.

I have no doubt that, if carefully searched, the Harlech group will yield similar fossils to those found in the Solva group, for the succession shown by the beds is also exceedingly like that at St. David's. The curious fossil *Oldhamia*, found many years ago in the Bray Head rocks, has not been found as yet in the Welsh or Scotch Cambrian rocks, and no further information as to its true nature has been obtained of late.

Prof. Hughes has recently been fortunate enough to discover what would seem to be the true basal (Conglomerate) beds of the Cambrian in Anglesea, and has traced, with much success, the same beds in the neighbourhood of Bangor and Caernarvon. In neither of these areas, however, have the Menevian, or even the majority of the Cambrian rocks been found. Probably these have been lost through faults. It is possible, however, that they may not have been deposited there. At Caernarvon and Bangor, as indicated by us years ago, they rest, as at Anglesea, on a pre-Cambrian axis.

Upper Cambrian.

The Upper Cambrian, consisting in ascending order of the Maentwrog, Ffestiniog, Dolgelly, and Tremadoc groups, attains to a thickness of about 6,000ft. Its lower groups are rather barren in organic remains, especially in comparison with the immediately underlying Menevian group. The upper groups, however, are rich, and contain many new forms. The labours of the late Mr. Salter and Mr. Belt in different parts of North Wales, and of Messrs. Homfray and Ash near Portmadoc, brought to light many new fossils, and have added much to our knowledge of these rocks.

It is to Mr. Belt we owe their arrangement into divisions as adopted in this paper. Their first recognition, however, we owe to the early researches of Prof. Sedgwick. Up to the year 1866 it was supposed that the Upper or Tremadoc group was a comparatively local formation, and not found out of North Wales. In that year, however, I was able to announce the discovery at St. David's of a large series of fossils nearly all new, but more nearly allied to those in this group than to any others known. Since then this group has been found at Shineton, in Shropshire, by Dr. Callaway, and many new species have been added by him to those previously known. He believes that the Shineton beds are chiefly of Lower Tremadoc age, or perhaps passage-beds between the Lingula flags and the Lower Tremadoc. He thinks also that he has detected the same beds at the base of the escarpment of the Stiper-stones, dipping under the Arenig series, and compares the sections and fossils to those worked out many years ago by Dr. Holl at Malvern. Prof. Hughes has also discovered rocks of

Tremadoc age in Anglesea, where they were previously unknown. He finds in these rocks fossils more characteristic of the St. David's Tremadoc rocks than of those of the immediate neighbourhood of Portmadoc. One of these fossils, however, *Neseuretus*, was also discovered some years ago by Prof. Hughes, Mr. Tawney, and myself, in a slate quarry between the Rivals and Pwllheli in the Lleyn Promontory of Caernarvonshire. The genus *Olenus* seems to occupy the position in the Upper Cambrian rocks which *Paradoxides* holds in the Lower. The most important of the new types which are found in the Upper Cambrian rocks are Phyllopods, Heteropods, Cephalopods, Lamellibranchs, Crinoids, Asteroids, and Graptolites, but several of these are found only in the Tremadoc group. The Tremadoc group, therefore, may be said, through many of its types of fossils, to link the Cambrian and the overlying Ordovian (Lower Silurian) formations together, whilst it yet marks very distinctly the horizon at which all the truly characteristic types in the primordial faunas are lost. Mr. Salter, in referring to these rocks in North Wales, in the Appendix to Prof. Ramsay's "Memoir," p. 250-251, says that this band (the Tremadoc Slates) "intimately connects the Lingula flags with the ordinary Silurian rocks," but "is nevertheless so distinct as to its fossil character from either." Again, "if we were to judge of mineral character alone, we should undoubtedly draw the chief line of separation above the hard arenaceous Lingula flags when the peculiar bivalves characteristic of that fauna become scarce enough. Yet the zoological change does not take place here, for with the recurrence of the black band the characteristic genera of the primordial zone return unmixed with those of Lower Silurian character. The black slates do not terminate abruptly, but gradually lose their deep tint, and become grey about the horizon of the flags which contain the *Dictyonema*. The character continues and increases upwards through the beds, which contain the following (Tremadoc) fauna. The beds are also harder, contain flaggy layers here and there, but are not at all common nor otherwise much different from those of the black slab series, except in colour and fossil contents."

At St. David's the Tremadoc rocks rest conformably in good coast sections on the Lingula flags, which contain here the usual fossil *Lingulella Davisii* in great abundance. They change gradually also

from the Lingula flags, first as bluish-grey slate and then into an earthy grey thick-bedded rock of peculiar tough texture, with some sandstone courses. As compared with the beds on the same horizon in North Wales, they would appear to have been on the whole deposited in shallower water. This probably accounts for some of the differences noticeable in the faunas in the two areas. The differences, however, are not such as would indicate the presence of a physical break at this point in either of the areas at the time. I am inclined to think that the rate of depression up to this point was tolerably even, but that a great and rather sudden change took place towards the close of the Tremadoc epoch, and that in consequence new conditions prevailed. I have entered rather fully into this question as it seems necessary to explain the reason why this line was adopted by the late Mr. Salter and myself to mark the division between Cambrian and Silurian as then known—now between Cambrian and Ordovian.

Ordovian.

This name * (or rather, its more lengthy equivalent, Ordovician) was given by Prof. C. Lapworth in 1879 to the groups classed by the late Sir C. Lyell, Mr. Salter, and myself, under the name Lower Silurian. The term is derived from the *Ordovices*,* a tribe which inhabited a large portion of North Wales during the time that the *Silures* and *Dimetæ* occupied other portions of Wales. The term is peculiarly appropriate also, as the tribe undoubtedly occupied the whole of the great Bala district where Sedgwick worked out the physical succession among a large portion of the rocks of this intermediate system.

Neither Murchison nor Sedgwick, however, could fairly lay claim to this formation as a whole. Sedgwick undoubtedly recognised the true position of the Arenig and Bala groups, but he included in these the Llandeilo rocks which Murchison had already explored and claimed as members of his system in South Wales and Shropshire. Both may be said to have done excellent work in these groups, while on the other hand, as stated by Lapworth, it cannot be denied that the work of both appears, "to our eyes, in the light of later discoveries, to have been more or less inaccurate or deficient." Moreover, "time has already done justice to the

* See "Geol. Mag.," Jan., 1879, p. 13.

value of the discoveries of both Murchison and Sedgwick by assigning them each a system in which their labours were accurate and complete." *

There can be no doubt also, as stated by Lapworth, "that the present needs of our science demand, with a unanimous voice that partizanship can no longer silence a distinct title for the rocks of the *Second Fauna*. The experiment of naming them in such a way as to recognise the claims of both Murchison and Sedgwick has been tried again and again with the same result. It has invariably ended in prolonging and greatly intensifying the original controversy." It is to be hoped, however, that ere long both parties will see the necessity of dividing the Lower Palæozoic Rocks into the three systems here defined, which are acknowledged to be characterised by three great and distinct faunas, and to be partially also marked off by physical boundaries. The controversies which have taken place have undoubtedly tended hitherto to prevent researches being carried on with that freedom which is necessary to scientific progress. The Sedgwickian and the Murchisonian schools may each feel at first that the sacrifice is great; still I am convinced that in the end the better feeling that will be produced, and the increased stimulus to research which it will give, will amply compensate them for it.

In papers published in 1872 and 1875, after examining several areas of the Tremadoc and Arenig rocks in North Wales, with Mr. Homfray and others, I ventured to propose that the boundary line between what we then recognised as Upper Cambrian and Lower Silurian should be slightly altered, as I found that the so-called Upper Tremadoc rocks in some places were identical with those called Arenig in other areas. The line which I then proposed is that which is here recognised as the actual boundary between Cambrian and Ordovian.

The Ordovian contains four distinct groups. Three of these are the well-known groups Arenig, Llandeilo, and Bala. I have, however, recently † interpolated a new group between the Arenig and Llandeilo under the name Llanvirn. I did so mainly at the suggestion of Prof. Lapworth, and because the fossil remains in these beds at a place called Llanvirn, near St. David's, are so distinct

* See "Geol. Mag.," Jan., 1879, p. 12.

† "Popular Science Review," October, 1881, p. 14.

from those found in the beds above and below that it seemed advisable they should be placed in a separate group. This group has an average thickness of about 2,000 feet. Most of the species found in it are new. The fauna which I worked out from the beds at Llanvirn, St. David's, in 1874 and previous years, is very rich in trilobites, and several genera appear here for the first time in the succession, as *Illænus*, *Illænopsis*, *Barrandea*, *Phacops*, *Placoparia*, and *Acidaspis*. The fauna also contains many graptolites, chiefly of the genera *Diplograptus* and *Didymograptus*, and there are also large Cephalopods, Gasteropods, Brachiopods, and Lamellibranchs. The lower portion of the so-called Llandeilo at Abereiddy Bay belongs rather to this group than to the typical Llandeilo, and is now included in this group.

At present the fauna of this group has been chiefly worked out at St. David's, but beds holding an equivalent position in the succession have been explored by Mr. Marr, near Caernarvon,* with much success. In an appendix to his paper,† published 1876, I ventured to correlate the beds with the Llanvirn rocks of St. David's, then known as Upper Arenig, and at the same time said that in "some respects the fauna would indicate a position intermediate between the Upper Arenig and Lower Llandeilo, a passage from the one into the other." There can be no doubt that these rocks will now have to be included in the Llanvirn group. Rocks on the same horizon were recognised years ago by Mr. Hopkinson and Prof. Lapworth, near Shelve; and I am informed by Dr. Callaway that he has also discovered some of the more typical fossils of the group, as *Placoparia*, &c., in rocks in that area.

By referring to Mr. Morton's interesting paper on the Shelve rocks,‡ it is clear that his list also contains some fossils belonging to this group. Prof. Lapworth, in a letter to me (Nov. 25th, 1881), says "that *Didymograptus Murchisoni* in its typical form is characteristic of the Llanvirn (Upper Group), but forms very like it range down into the Arenig below. The *D. Murchisoni* Zone (Upper Llanvirn) is beautifully developed at Shelve, as well as in the Carneddau Hills near Builth, and close to the town of

* "Quart. Journ. Geol. Soc.," vol. xxxii., p. 134.
† *Ibid.*, p. 136.
‡ "Proceed. Geol. Soc.," Liverpool, 1868-1869.

Llandeilo. I have examined it in all these localities." Rocks on this horizon have also been recently explored by Prof. Hughes with much success on the north coast of Anglesea.

The underlying or true Arenig rocks have yielded to our researches at St. David's a new and important fauna of Graptolites, and these have been carefully described by Messrs. Hopkinson and Lapworth. To these authors also we owe the recognition of many of these forms in equivalent rocks at Shelve.

The so-called Skiddaw slates, so well known through the researches of Messrs. Harkness and Nicholson, are chiefly on the horizon of the Arenig rocks, but in part also are the equivalents of our Llanvirn group.

The two upper groups, Llandeilo, and Bala, have not of late years been much worked in Wales, though in other areas very many important additions to our knowledge of them have been made. Of these I would especially call attention to the remarkable researches of Prof. C. Lapworth in the Southern Highlands of Scotland, which have been published in the "Quart. Journ. Geol. Soc.,"* and elsewhere. Previous to his researches there was much confusion as to the proper succession of the rocks in this area, and as to their representatives elsewhere. His discoveries, however, have now enabled him "to propose a new theory of the succession which is in consonance both with the stratigraphical and palæontographical evidences, and brings the South Scottish Silurians into perfect harmony with those of other countries. The district which has yielded the most conclusive proofs of the true sequence lies in the neighbourhood of Moffat. At the head of Moffatdale a deep gorge known as Dobb's Linn affords a magnificent section of the black graptolite shales." He has shown that the black shales of this spot are arranged in an anticlinal form, and come out conformably from below the greywackès of the district. "These black shales fall into the three natural divisions denominated the Glenkiln, Hartfell, and Birkhill shales. Each of these three divisions contains a special graptolite fauna of its own, and breaks up again into many subordinate zones individualized by special mineralogical and palæontological distinctions." † In Ireland the valuable researches of Mr.

* Vol. xxxiv.

† "Trans. Geol. Soc.," Glasgow, p. 80, April, 1878.

Swanston, F.G.S., have shown, according to Lapworth,* that the black shales of County Down, though excessively contorted and shattered, exhibit a general grouping similar to, if not identical with, that of the Moffat Series in Scotland, the Glenkiln (Llandeilo), Hartfell (Bala), and the Birkhill (Lower Llandovery) being all represented there.

The Bala (or Caradoc) rocks of the Girvan district and their fossils have also been described in elaborate memoirs by Prof. Nicholson and Mr. R. Etheridge, Jun. The additions to the fauna of the Caradoc contained in these memoirs are highly important. Though, as already stated, the Welsh Llandeilo and Bala groups have not furnished of late many new forms, and have not been worked with much zeal, yet the information given in Prof. Ramsay's memoir, and especially in the Appendix by Mr. Salter, in 1866, shows clearly that they had, up to that time, received an unusual amount of attention, Sedgwick, Murchison, McCoy, Salter, and the officers of the Geological Survey, having all devoted much critical attention to them.

During the Ordovian period, volcanic eruptions, chiefly beneath the sea, were frequent, especially in the Welsh areas.

It is possible also, as suggested by Prof. Ramsay, that islands may have in consequence been formed, which sometimes raised their craters for various periods above the water. There is no evidence, however, that any portion of the crust itself was raised above sea level until towards the close of the Bala epoch.

Hence these rocks are made to form the upper boundary of the Ordovian. The physical break at this point, however, does not appear to have extended over all the British area. The evidence of it is very marked in the more central portions of Wales, but less so as we travel to the north-east into Denbighshire, or to the south-west into Cardiganshire and Pembrokeshire.

Silurian.

This name, as all know, was given by the late Sir R. Murchison to the fossiliferous rocks in Shropshire, which lie immediately below the Old Red Sandstone, and amongst which he had been working assiduously for years, with great success. The term was

* "Proceed. Belfast Naturalists' Field Club." Appendix, 1876-1877, p. 125.

afterwards, as already stated, extended from time to time by him and his followers, in a downward direction, to include rocks in all areas in which fossils were found, and it was with no little surprise that I noticed in the Appendix to "Siluria," 1867, p. 550, in a paragraph referring to a discovery I had just then made at St. David's, an attempt to carry this downward extension to a most unwarrantable extent by using the term "Primordial Silurian." It has been quite clear, for years, to those who have been working among these old rocks, that the term ultimately would have to be limited to the rocks concerning which there could be no controversy, and where his work is acknowledged to have been complete as far as was possible at the time. The upward limit has remained tolerably correct from the first.

The groups which we include, therefore, at present in the Silurian from below upwards, are the Llandovery, Wenlock, and Ludlow.

The lowest deposits in this system, as was pointed out to have been the case at the base of the Cambrian, in consequence of the presence of land areas, vary in thickness as we approach to or are distant from those areas. The Llandovery group, in Pembrokeshire, and, as has been recently shown by Mr. Keeping,* in Cardiganshire, attains to a great thickness. In these areas also the Lower Llandovery rocks appear to rest quite conformably on the Bala beds. On the other hand, the evidence that a physical change was taking place in other parts of the Welsh and some adjoining areas at this time is most marked. The lower beds are entirely absent in the Longmynd and other Shropshire areas, and the whole group, which I believe cannot be much less than two thousand feet in thickness in Pembrokeshire, and is also of great thickness in Cardiganshire, as proved by the very important researches of Mr. Keeping, is represented in the Shropshire areas by about 100 feet of conglomerates and sandstones.

In Denbighshire, where they have been explored by Prof. Hughes, Mr. Marr, Mr. Ruddy and myself, only a moderate thickness of the beds occurs. I have in previous papers attempted to show that there was no actual evidence of an unconformity between the Bala and the Lower Llandovery rocks about Corwen, in Merionethshire, or in Denbighshire.

* "Quart. Journ. Geol. Soc.," May, 1881.

I believe that this area, like that in the south-west, was under water during the time that other Welsh areas were above water, and that it also received sediments during the time that the majority of the Lower and Upper Llandovery rocks of South Wales were being deposited. As the typical fossils of the Upper Llandovery rocks of South Wales and of May Hill have not been discovered in Denbighshire, it is rather difficult to correlate the beds correctly with those of the south, but I am inclined to believe that at least the lower portion of the so-called Denbighshire grit series, with the so-called Tarannon shales, will have to be placed on that horizon, or at least entirely below the true Wenlock beds of Shropshire. I have just heard from Prof. Lapworth, however, that he has found graptolites characteristic of the Middle and Lower Llandovery rocks, as known in Scotland, in the beds near Corwen and elsewhere, immediately underlying the Tarannon shales. In his letter to me (Nov. 25th) he says that he feels "quite confident that the lower, middle, and upper Llandovery are all present in North Wales, but in a greatly attenuated form—that the Tarannon is grandly developed, that the Penyglog beds are the equivalents of the Pencerrig beds of Builth with *Cyrtograptus Murchisoni*, which are there mapped as the base of the Wenlock, and that the Denbigh Grits, therefore, are in the so-called Wenlock shale of South Wales as mapped by Murchison and his successors." Before the true May Hill beds of Sedgwick can be properly correlated with these beds, further researches, it seems to me, are still necessary.

The labours bestowed, of late years, upon the Llandovery rocks by Lapworth in Scotland, by Hughes and Maw in Wales, and in the lake district by Harkness and Nicholson, also in the last-mentioned area, and by Keeping in Central and West Wales, have already removed most of the difficulties connected with these rocks which have baffled the attempts made to correlate them in different areas. Doubtless these difficulties were in great part due to the fact that an important physical change had taken place just before these sediments were deposited, and that they therefore varied in their mineral character in different areas, and that the fauna also was more or less affected by these local physical conditions. The evidence of these land areas in parts of Wales is made clear also by the fact, which I recently made known, that undoubted remains of land plants occur in

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TABLE OF BRITISH EOZOIC AND LOWER PALÆOZOIC STRATA (1881).

PERIOD.	SYSTEMS OR FORMATIONS.	GROUPS.	PETROLOGICAL CHARACTERS.	CHARACTERISTIC TYPES AND ORDER OF APPEARANCE OF LIFE.	LOCALITIES WHERE EXPOSED.
		Ludlow ...	**Grits, Sandstones, Shales, and Limestone.**	**Pisces**	Ludlow, Ledbury, Downton, Kington, **Lesmahago, Whitcliffe, Malvern, Long**
EOZOIC.	ARVONIAN.	Holyhead...	Schistose and Compact Quartz Rocks	... ...	Llanhowell, near St. David's, and Holyhead Mountain in Anglesey.
		Treffgarn...	Breccias, Hälleflintas, and Quartz Felsites	... ...	Treffgarn Mountain, Roch Castle and near St. David's in Pembrokeshire, Bodafon Mountain and Ty Croes in Anglesey, and several ridges in Caernarvonshire.
	DIMETIAN.	Porthlisky	Highly Quartzose Gneissic Rocks, with Limestone Bands	... ...	Porthclais and Porthlisky near St. David's, Anglesey, and North-western Highlands of Scotland.
		Bryn-y-garn	Granitoid and Gneissic Rocks. Usually of a white, light grey, greenish, or pinkish colour	... ...	St. David's and Brawdy in Pembrokeshire, Twt Hill, and Rhos Hirwain, Caernarvonshire. Anglesey, and North-western Highlands of Scotland.
	LEWISIAN.	... ...	Massive Hornblendic Gneiss. Of a black, dark grey or rusty colour	... ...	The Hebrides and North-west Coast of Scotland, North-west of Ireland, and Malvern Hills in England.

abundance in the Penyglog slate quarry at the base of the Denbigh Grit series near Corwen, North Wales. The specimens found are all in a fragmentary condition, showing that they must have drifted into their present positions from some neighbouring land.

By the time the Wenlock rocks were deposited, most of the land had again been submerged, and the sediments are such as would accumulate in a quiet and moderately deep sea.

The most important researches of late years connected with the Wenlock and Ludlow groups are those of Prof. Lapworth and Mr. Hopkinson among the Graptolites, Messrs. Davidson and Maw among the Brachiopoda, Dr. Woodward on the Eurypterida, Prof. Rupert Jones on the Ostracoda, and Mr. Vine on the Polyzoa. In the admirable paper by Prof. Sollas* on the Silurian rocks near Cardiff, many facts of great importance are also given.

The important discovery of fish remains in the Ludlow made many years ago, chiefly by Sir R. Murchison, is still; as far as I am aware, the earliest indication of vertebrate life in the Silurian Rocks. It is to be hoped, however, that further researches will reveal the presence of still earlier forms, both marine and freshwater. My recent researches among the beds containing the land plants near Corwen have raised these hopes, for it is well known that up to the time of this discovery the earliest land plants found in Britain were fragments and supposed spores found in association with the vertebrate remains in the Ludlow rocks.

The subjoined Table shows the succession of the strata up to this point as at present recognised in Britain.

* "Quart. Journ. Geol. Soc.," May, 1881.

ORDINARY MEETING.

JANUARY 6, 1882.

W. H. HUDLESTON, Esq., M.A., F.G.S., President in the Chair.

The list of donations to the library since the last meeting was read, and the thanks of the Association returned to the donors.

The following were elected members of the Association :— Wm. Bushby, Esq.; Geo. Biddell, Esq.; W. M. Crossland, Esq., M.Inst.C.E.; Joseph Faulding, Esq.; G. J. Jones, Esq.; Wm. Smith, Esq.; Herbert Wailes, Esq.; Wm. White, Esq.

The following paper was then read :

ON LAKES AND THEIR ORIGIN.

BY PROF. P. MARTIN DUNCAN, F.R.S., V.P. GEOL. SOC.

There is no subject connected with the present and past aspects of nature, which presents greater difficulties than that which relates to lakes. It is true that some kinds of these inland collections of water are very readily comprehended, so far as their causation is concerned, such, for instance, as the crater lakes of Germany, Italy, and Australia, or those bodies of water which are hemmed in by landslips or by ice, and the numerous large but shallow pieces of water in swampy districts, even if these rest upon a hard bottom.

But the larger lakes of the great continents, situated at very different altitudes, and some of them of profound depth, are excessively difficult to account for.

Imagination, however, has not been allowed to rust for want of scientific use, and many hypotheses, some ingenious and clever in the extreme, have enlivened and often materially influenced geological thought. For the lake is not a thing of to-day; it is the outcome of the past, a relic of former and different aspects of nature.

In explaining natural phenomena, the successful hypothesis, if it is to develop into a useful theory, must include the whole truth. And yet one fascinating hypothesis of the origin of lakes, omits the consideration of the origin and period of introduction of the animals of the lake, whilst another does not give any evidence that the physics of the deep sea have been comprehended by its author.

Thus the hypothesis of the glacial origin of lakes does not consider the biological question, and that which relegates the formation of large lakes to the former action of erosion on the sea floor, omits the fact that the sea does not erode at a depth of some scores of yards.

The relation of the natural history of the animals of lakes to their method of origin has been recognised as of importance by zoologists alone. The geologist, pure and simple, has hidden up the biological skeleton in his darkest closet.

Really one of the most interesting of the subjects connected with lakes is the study of the modifications which marine invertebrate forms undergo in their adaptation to a freshwater life; and another relates to this possible origin of many terrestrial species. I ventured to bring some of these facts and ideas before the Geological Society in one of my presidential addresses. In it the relationships of marine and fresh water animals were considered, and also the existence of marine forms and slightly modified marine forms in lakes remote from the sea. Moreover, the address stated, "It would be impossible for a fauna and a flora, like those of the great American, Scandinavian, and larger Swiss lakes, to have existed during the formation of a lake by glacial erosion. If the lakes had that origin, the fish, mollusca, and crustacea, must have been introduced subsequently. But, in many instances, there is no possibility of the migration of the Salmonoids to and from the lake, or of the crustacea into it. There has not been any since the country around received its relative level, and that was, in most instances, before the period of land glaciation." The Swiss lakes were in my thoughts, and the address proceeded: "There is no doubt that the lacustrine forms are not much influenced by cold. The depths of the Swiss lakes have a persistent temperature of from 40° to 60° F., yet the piscine forms are not surface ones only. The temperature of the ice-covered tarns of the extreme north of Europe is not sufficient to destroy the Charrs." Finally, it was stated, "Deep lakes cannot have been formed by their running water alone, and certainly the study of their faunas carries back their date to a time when totally different physical and geographical conditions prevailed."

It would be simple waste of time, in addressing an assemblage of geologists, to venture to explain Ramsay's charming hypothesis of the erosion of lakes by glaciers. It is known to you all, and it

is also a fact that very distinguished geologists and physicists, who have paid great attention to the study of ice and glaciers, deny the possibility of lake erosion by stone carried in ice, or by the glacier stream.

Favre, Dana, Whitney, Bonney and Drew are amongst the disbelievers, and those amongst us, whose minds are sceptical, will do well to notice that the retreating glaciers of the Alps leave convex roundings on their floors, and not little concave hollows. A careful investigation of the work done by glaciers, on the grandest scale, leads to the belief that they have not originated their valleys, and that these grand features of the mountain are being slowly worn larger.

But admitting that fish and crustacea could not have originated or existed in lakes and hollows, whilst the presumed erosive process prevailed, it is perfectly evident that the lakes in certain latitudes and altitudes were in the midst of severe glaciation during the glacial period.

That deep valleys were filled with nevé and glacier, there is no doubt, and it is equally certain that the lakes were frozen over during the winter to a great depth, and that the ice thawed, and moved, and floated stone in the hot summer.

Sir George Nares remarks that he encamped on a projecting spit of land, in May, 1876, not far from the winter quarters of the Arctic Expedition, and close to Dumbell Lakes. "Hill and plain were covered with snow. The ice in Dumbell Lake, which had not yet begun to thaw, was 91½ inches thick, and the water from below, when reached, rose to within 8½ inches of the surface of the ice. All the water in this lake had certainly not been frozen during the past winter, and afterwards we found it was well stocked with a small species of Charr. Indeed, we did not ascertain that any of the lakes that contained fish froze to the bottom. The evidence tended to the contrary." This is satisfactory evidence that in localities where the cold is now as severe as it was further south during the glacial period, lakes exist with fish.

Many lakes in districts which present abundant evidence of the reign of ice, and show no traces of subsidence since the glacial period, contain Charrs. And in many of the fresh water lakes of Norway, and of Sweden, there are marine crustacea, such as the red Copepod *Harpacticus chelifer*, and such marine crustacea as *Mysis relicta*, *Gammarus cancelloides*, and species of *Pantoporeia*.

There has been no subsidence there since the glacial period.

This fauna, as a whole, is not only common in those inland lakes, but it has a vast lacustrine distribution in America and Asia. In some of the fjord-shaped Scandinavian lakes with this fauna, is *Cottus quadricornis*, a marine fish, Many years since, Lovén, that accurate naturalist, knew all this, and asserted that the lakes of his native country, thus provided, had never been in relation to the sea since the glacial period, and that they could not have been formed by glaciers.

The Lake of Geneva, and its neighbour, of Neuchatel, contain lake Trout, fresh water Bryozoa, and amongst the gasteropods *Limnæus pereger*, which has its respiratory chamber modified into branchiæ, and is a deep water form. There are large Copepods of the genus Bythotrephe and Leptodora, and there are two members of the Scandinavian crustacean lake fauna. There are Amphipoda, and Cladocera, Isopoda and Ostracoda. The greater part of this fauna lives on the soft mud of the floor, which is at a depth of 984 feet. The Copepods swim by night, and descend into the gloom of the depths by day. This is a very old fauna which could not have been introduced since the glacial period.

Now the lakes are not choked with moraine matter, there is no current on their floor to erode, and the great travelled blocks, found far beyond and above the present level of the Lake of Geneva, were carried down by the Rhone glacier to the lake, and thence moved by surface ice during times of great water level, probably at the very end of the glacial epoch. The Lake of Geneva has a fault on its south margin, along the Triassic rocks; on the north, the secondary and tertiary strata dip in a roll to the lake, and on the east of the lake, on either side of the valley of the Rhone, there are tremendous reversals of strata to the south. There is no evidence whatever to show that any animals could have migrated into the lake since the glacial period, and the evidence is as strong in relation to the Lake of Neuchatel. The Lake of Brientz is 620 feet higher than the Lake of Geneva, and is 2,000 feet deep or lower at the floor than the sea level. Probably it was in the nevé during the glacial epoch.

Between the Rhine and the Mont Blanc chain, near Annecy, there is Lake Bourget, and it contains a Blenny, a marine form, and there is no possibility of fish entering now from the sea. In fact, the faunas of the other Swiss lakes indicate a great antiquity, and that they were stocked under marine conditions and before the glacial period.

The great Italian lakes, south of the Alps, have their floors

deeper than the sea level by hundreds of feet. They contain species of the marine genera, Gobius, Blennius, and Atherina, and the shape of the floor, especially of the Lake of Como, and the depth are quite opposed to the notion that glacier excavation prevailed, and certainly there has been no subsidence since the glacial period.

In the far east of the Russian Empire, north of the Altai, and higher than the source of the Lena and Amoor, and on their water parting, is Lake Baikal. It is even now in a severe climate.

It is a long, narrow lake, a holy lake, a grand feature in a dreary district of rugged hills, of granites, syenites, crystalline schists, limestones, and conglomerates. It is 12,500 square miles in extent, and the hills to the north, between it and the distant ocean, are from 3,500 to 4,000 feet high. The lake is 397 miles long, and from four to thirteen miles broad, and 1,800 feet above sea level. It is on a table land with a very gentle slope to the sea, which extends like a gigantic water parting, for hundreds of miles to Behring's Straits. Numerous minor lakes are in the neighbourhood, and they all form part of a very grand water system. The great lake receives large rivers, which drain a district as large as the United Kingdom, and only one small river, the Angora, arises from it, and flows down a rapid and torrential course to the Yenisei River. Baikal is 1,200 miles from the sea.

The lake is of fresh water and is frozen over in winter, by more than 40 inches of ice, and the summer is short.

A promontory nearly cuts the lake in half, and in many parts vertical cliffs of rock stand up out of great depths, and the bottom is singularly uneven in spite of the large number of streams which enter and deposit. Part of the lake is 800 feet in depth, but in laying a telegraph cable it was found to be much deeper in some places, and for many miles.

A ridge in the midst of the lake is 3,300 feet deep, and then the floor slopes to 3,600, 4,200, 3,900, 4,200 feet, that is to say to far below sea level. At the base of the cliffs the depth of 330 feet is met with. The depth is therefore considerable, and the floor in places is lower than the level of the distant sea by at least 2,000 feet. The whole district is ice-marked, and yet the quantity of drift in the lake is inappreciable. It is impossible that there can be any scour going on on the floor.

The temperature of the bottom (constant) is 3·5° Centigrade, but the surface is often covered by many feet of ice. It is a

greater lake than Tanganyika, and there are terraces around it denoting a former extension.

This lake has *Salmon*, *Trout*, and *Sturgeon* in it, and a dwarfed Cod or *Gadoid* of the genus *Comophorus*.

One of the seals, *Phoca sibirica*, a variety of *Phoca vitulina* of the N. Pacific, inhabits Lake Baikal, and another lake called Lake Oron, which is far to the north and near the river Vikin, a branch of the Lena.

The *marine crustacea* of the Scandinavian fresh water lakes are also found in Baikal, *Mysis relicta* and *Gammarus cancelloides*.

The seal, the gadoid, and the crustacea, are the descendants of those which lived in the sea of which the Baikal area once formed a part. The Baikal area has not subsided since the glacial period, and nothing can get into it from the sea.

Lake Baikal is a more decided and greater example of a method of origin which applies also to the Caspian and Aral Lakes, for such they are, although called seas.

The surface of the Caspian is below that of the Black Sea by 84 feet, and its depth attains in some places 3,000 feet, being much less in the north. It is a vast sheet of water, 740 miles long and from 210 to 243 miles broad.

Away to the east is Aral, 117 feet above the level of the Caspian. They were formerly connected along what is now a dry, low valley, on the floor of which the common shells of the Caspian are found—*Cardium edule*, *Cardium trigonoides*.

Both lakes are supplied by great rivers, and are saline to a certain extent, and more so away from the rivers which enter them, and the surrounding soils often contain salt. They come under the rule that lakes without rivers leading from them, are brackish or salt.

Aral is not so salt as the Caspian, but it is shallow, and is 72 feet deep in the middle and 216 on the western side, near very perpendicular cliffs which are in relation to a plateau. It occupies 24,536 square miles.

The Caspian fauna consists of a *Phoca* (a variety of *P. fœtida* of the Atlantic) and of *Salmon*, *Sturgeons*, *Sturlets*. Aral has no seal, and its fish are of the same genera as those of the Caspian. In both of the faunas these is a mixture of marine and fresh water types.

Dried-up lakes and terraces denote a former extension of both of these lakes, and it appears impossible to resist the evidence that

these great Asiatic inland waters, despite their differences of altitude, were once parts of the sea.

Between the Caspian and the Black Sea, and east of Erivan in the Ararat district, is a plateau between ridges of mountains, some being extinct volcanoes. The height is 5,800 feet above the Black Sea. A lake is there, Lake Goktcha, twice as large as the Lake of Geneva, 350 feet deep in the middle. There is sweet water in the neighbourhood of the incoming rivers, but it is brackish elsewhere. There is no outlet, and Trout and Salmon exist in vast numbers. The lake is covered with ice in the winter. The fauna must have been introduced when the aspect of nature there was very different to what it is now.

The next group of lakes to be considered is amongst the most extraordinary phenomena of physical geography.

Lakes do not exist along the lines of the Glacier valleys to the south of the Himalayas, but they are found at great altitudes, on an irregular table land which stretches from the Kuen Lun Mountains through Western Tibet eastward, and to the head waters of the rivers watering China. To the south are the greatest elevations of the Himalayas, and to the north a more or less gradual slope to Turkestan. The most important landmarks are the Indus and Sutlej rivers at their origin and early east to west course; and extending far to the east and south is the Brahmaputra or the Tsampou. There are lakes north and south of these east and west running rivers, separated by many hundreds of miles.

Firstly—North of the Indus, south of Kotan, and east of the line joining Yarkand and Leh (78° E. long.) are the *Pangong* series and others. One is 100 miles long and seven broad, and the depth is 136 feet; the height of the plateau is 15,000 to 16,000 feet.

Secondly—South of the line of the Indus and Sutlej, but to the east of those rivers, in Nari Khorsum or Hundes, is *Langcho* lake, which is 13,000 to 15,000 feet above sea level, and *Chomopang* or *Manasarowar* lake. To the east of this last, a range of hills separates the valley of the Brahmaputra or Tsampou.

Far away to the east (10° long.), north of the easterly flowing river, is a small lake 15,190 feet above sea level, and separated from the river, by a pass of 17,200 feet. This Tangri lake is embedded in hills, and is 45 miles long by 25 broad. It contains islands,

is the recipient of the waters of two considerable rivers, has no outlet, is brackish, yet freezes. There are cyprinoid fish and mollusca in these lakes. Hot springs, 130-137° F., exist to the south of the area. South of the lake is a grand range of peaks and glaciers, 25,000 feet being attained.

On the southern side of the river Tsampou are several lakes—Yemdok, at an altitude of 13,500 feet, being the most noteworthy. Still further north-eastwards is the Kakonur lake, on the road from Lhassa to Pekin.

The Himalayan moraines under present formation reach down on the south of the chain to 14,000 to 16,000 feet, and are much higher to the north. The drift of the river-wearing and of the old glaciation of the Himalayas is found up to 16,000 feet, and yet these lakes are not filled with it, and they contain in some instances, fish and mollusca. It appears that every geologist who has visited these upland regions, notices the slight relics of the presupposed ice action. Of fluviatile and subaerial erosion there is abundant evidence, and of much that occurred before the glacial period.

The Pangong series of saline lakes shows very distinctly, especially Lake Tso Morisi, 248 feet deep, that they are part of a long valley, stopped up here and there by the alluvial deposits of streams running more or less across its line. Many small lakes are marked in this great upland district on the survey map of India, and nearly all tell the same story. They have rarely any outlet, are more or less brackish, are at great elevations 15,000 feet being the highest point. They are on the table land, and not in the line of the glaciers, but on the line of strike of the mountain mass and in old valleys of fluviatile erosion. No marine strata, younger than the nummulitic, are near, the Himalayas having attained their greatest development in the Pliocene age, before the glacial epoch.

The valleys of the Himalayas were mainly worn before the glacial period, and fluviatile drift fills up enormous old lakes. The remains of old glacial action are to be traced on the river drift to 8,000 or 10,000 feet above the sea level.

Before passing on, it is as well to sum up the bearings of the facts just considered. Lakes of very different elevations, many within the areas of present and past glaciation, are deep, uneven on their floor, and are not crowded with glacial *débris*; moreover they contain a fauna, a large portion of which indicates a marine origin. This fauna cannot have been introduced in most places

since the glacial period, and its presence is incompatible with the erosion of such lakes by glaciers. But the sea could not excavate such lakes any more than glaciers; its eroding power, except in such places as the tidal bay of Fundy, being restricted to a few fathoms of depth.

The terrestrial condition must, therefore, have preceded the marine, and the lakes were worn, in the first instance, by rain and rivers, and then their areas participated in the crushing, subsidence, faulting, and upheaval which have affected all their regions during the later tertiary ages. The fauna has lasted on, and is a relic of the past.

Eastern Africa, a grand country of table land, has of late years been the subject of much geographical research, and everybody is aware of the wonderful travels of Livingstone, Speke, Stanley, Cameron, and Burton. The search for the sources of the Nile abolished the mountains of the moon, and established the existence of a grand series of lakes, some in relation to that great river, and others feeding the Zambesi to the south and east, and possibly the Congo to the west. These lakes are separated from the sea to the east, by the Abyssinian table lands and mountains, by the Somali country, and the chain of hills bordering the Mozambique Channel. They are isolated by high land, and they are at considerable elevations above sea level.

From the Red Sea at Massovah south to Somali-land there are not only high mountains (that of Kenia reaching 18,000 feet), but abundant evidences of great volcanic activity having taken place in late geological times, such as extinct craters, hot springs, and lava flows. These extend into Abyssinia, where volcanic energy developed itself on a very grand scale. Moreover, there is a decided parallelism between some of the lakes and the strike of the mountains, and they occupy vast valleys, often surrounded by high ground or table-land. No tertiary strata are known in the districts, which consist, it is said, of crystalline and schistose rocks.

The Nilotic group of lakes are large, and they are the Victoria Nyanza, Albert Nyanza, Dembea lake, and probably the Boringo lake. The Victoria Nyanza is 3,300 feet above the Albert, which is 2,500 feet above sea level. Dembea is at an elevation of 6,000 feet on the Abyssinian plateau.

South is Tanganyika, a lake separated from those just mentioned by hills of 10,000 feet, and enclosed by plateaux and steep

mountain masses. There is a small outlet, not always permeable, but it is mentioned by Cameron. The water is sweet, and the height is 2,756 feet. If it joins the Congo, then it is associated with the next group of lakes in relation to the rivers Lualuba and Congo; Bembo, 4,000 feet, 150 miles east and west by 75; Moero and Ulenge, 2,000 feet. Finally, Nyassa, 1,300 feet, a north and south lake, opens into the Zambesi by the Shir, and has two lakes associated with its outlets. A great mountain system, remote from that of the coast range, environs it.

In considering these vast lakes which are supplied by numerous rivers, one is struck by the presence of islands in some of them, of scarped hills surrounding others, and terraces rising from them. For instance terraces occur, denoting a former higher level to the water of Nyanza, and there are levels at 3,800, 4,500, and 5,100 feet. There are no evidences of volcanic action in the immediate neighbourhood. Unfortunately these lakes have yet to be carefully examined. The depths are not satisfactorily given, the geological sections are not dealt with, and finally, the faunas of the lakes have not been described.

But Edgar Smith, of the British Museum, has lately written on the mollusca of Tanganyika, and finds that some resemble marine forms in a most remarkable manner. They are not identical with known forms, but the spinose ornamentation would immediately suggest marine progenitors. Moreover, they belong to a genus found to exist in the lower tertiary of North America.

The difficulty of accounting for these lakes is great, but they were not of glacial origin, and the sea did not erode them.

That vast changes of level have occurred in the north-east of Africa and far away to the north, and along the line of the Jordan, is evident. There is the grand fissure of the salt Dead Sea, which is 1,390 feet below that of the Mediterranean, and the Lake of Galilee, 380 feet below sea level. The Jordan's waters lose themselves in the salt sea. Yet Günther recognises Nile fish in the sweet waters of Galilee.

Denudation, when the surface was higher, faulting and steady local subsidence to below sea level, and then diminution in breadth and increase in depth, produced during the lateral thrusts which developed the last mountain masses in the neighbourhood, and last of all upheaval. These may have produced the lakes, while volcanic undermining may also have had its effects.

It is now necessary, in conclusion, to pass to a totally different series of lakes, the grandest in the world in point of size, and which, although they are not at great altitudes above the sea, have their floors for the most part lower than sea level. The greatest series of lakes is in North America, and the surface covered by their water is greater than that of any other lacustrine area.

Lake Superior is a lake of irregular outline, of vast dimensions, and land-locked, except on the south-east, where it enters a system of two lakes, which have a more or less longitudinal direction. One of these, Lake Huron, has an irregular outline and a considerable development of islands in its north-east part, and the other, Lake Michigan, is a long, narrow lake whose southern extremity is further south than that of Lake Huron, the territory of Michigan separates these lakes, which latter passes by the St. Clair into the small lake St. Clair, and thence to Lake Erie. Lake Erie, a long and comparatively narrow lake, has its long axis at right angles to that of Huron, and passes by Niagara Falls and River, to Ontario, a great lake whose water flows into the St. Lawrence River.

The dimensions of these lakes and their altitude above sea level diminish to the south-east, as may be seen by the following list:—

	Altitude.	Depth.
Superior ...	630 feet	800—900—1,026 feet
Michigan ...	600 „	870
Huron ...	600 „	204—750
Erie ...	563 „	72—210
Ontario ...	234 „	400—738

Lake Superior may be compared to a vast crescentic basin with a high rocky rim scooped out of the plateau extending from the Alleghanies to the Mississippi River; the high land to the north divides the water flow, some going north to Hudson's Bay, and some south to Lake Superior. Its greatest length must be 360 miles (north and south 140), and it is 1,500 in circumference. The mountainous rim is almost unbroken, and its height ranges from 300 to 1,300 feet. The northern sides of the lake have abrupt rocks, and the southern sloped ones. To the north the shores are composed of large and angular stones, and sand is hardly seen, except at the mouths of the large rivers; but to the south the beaches are low and sandy, and the rivers are frequently

filled up. The northern and eastern rivers enter it by rapids. This huge basin is filled with clear, pure water, faintly greenish in hue, and of from 37-40° F. in the summer. It is 630 feet above sea level (627 feet, Bayfield).

The northern shores of Lake Superior and the mountainous country inland, show unmistakable ice-work. The rocks are polished, scratched, smoothed, rounded, almost uniformly in the direction of north and south. Agassiz noticed that for 1,500 miles the heterogeneous materials of which the rocks consist, are cut down to one continuous level, adapting itself, however to the general undulations of the country. The hills show abrupt slopes and rough and sharp curves to the south, but they are smoothed off towards the north. Many valleys, running more or less east and west, are crossed by north and south scratches; and here and there on the sides of the lake, and amongst its islands there are confused striæ, indicating no prevailing direction of ice movement. Accumulations of glacial drift, more or less stratified, are found on the smoothed surfaces, and boulders are mingled with them; and all these materials are scratched and more or less polished.

The floor of Lake Superior is gently undulating, with steep margins. The mean depth is 800 feet below the present surface. Some soundings exceed 900 feet, and one is 1,026 feet. The greatest depths are nearer the shore than the centre, which is uniform and a great dead level, and on the north-west the great depths are close to the shore. Hence the floor of the lake is below sea level, is flat in the greater part, and deep near the rim. The lake floor, to the north, consists of the bases of the same rugged hills of crystalline and metamorphic rocks which bound the lake. The floor throughout is not covered with any great depth of drift deposit, hard and rocky bottoms being constantly found in sounding; but dredging brings up fine drab or bluish clay. The temperature below 200 feet is 39°.

Two very important physical phenomena are to be considered. First, terraces of sand and shingle covering striated and polished rocks, ascend in grand steps. The highest terrace is 300 feet above the present lake level. Corresponding terraces and slopes, one over the other, are found on the flanks of the river valleys entering the lake. The sand and shingle is worn-down drift. The second fact is, that the great depths of the lake form a channel of 200 miles in length, eroded out of the north-west part of the lake's floor.

That the terraces were produced by shore action of the water of the lake, is beyond doubt; but was the water ever 300 feet higher than it is now? Had it been so, it would have overwhelmed everything to the south; and then how should we account for the lower terraces?

Again, how could a deep channel 200 miles in length, and some 20 or 30 broad, be formed in hard rocks at a depth below sea level?

The terraces were produced during slow upheaval and occasional stationary conditions, and the channel belongs to an age long anterior, and which relates to the initiation of the lake.

A considerable vertebrate and invertebrate fauna exists which cannot have co-existed with the phenomena of rock erosion by ice, nor has it been introduced since the glacial period.

Amongst the fauna are the Lepidosteus, or Gar Pike—a genus of ganoid freshwater fish, found also in the great American rivers; peculiar species of sturgeon, Amia—a siluroid, percoid fish closely resembling European forms, sticklebacks, pikes, gadoids—of the genus Lota, Coregonus or White fish of the salmonidæ, carp, gobies, roach, the lake herring, and lampreys.

This fauna is essentially a fresh water and continental one, and the affinities of its species with those of the other parts of the North American continent and Europe-Asia, denote a long duration of terrestrial conditions. The Lepidostei and the Siluroids point to a very considerable antiquity.

The invertebrate fauna contains the genera *Limnæa*, *Physa*, and *Planorbis* amongst the freshwater shells, and a *Hydra* and *Tubifex*. But the crustacea, *Mysis relicta* and *Pontoporeia affinis*, are present, and certainly they had a marine ancestry, as in the European lakes already mentioned.

As the boundaries of this great lake are so rocky, they present a great distinction from those of the other lakes, which, as they pass southwards, become flat at their margins, and, as far as scenery is concerned, often resemble the sides of great ponds.

Lake Michigan has a very level floor, deepest in the northern part, and shallowing to the south. It is for the most part a very plain surface, 600 feet deep to the north and 300 feet to the south. The deepest sounding is 870 feet, and this part of the floor is below sea level, but is on a higher level than the profound depths of Lake Superior. The pitch is often not more than 40 feet in a

mile, yet near the eastern side there is a line along which the depth increases from 102 feet to 456 feet, so that there is, as in Lake Superior, a submerged ravine or canon. The *Mysis* and *Gammarus* are present, and *Triglopsis*, a marine-looking fish.

Lake Huron, 600 feet above the sea, is shallow in parts, being seldom 210 feet deep in the south-west, but it has a channel 300 feet in the midst. Shallow water also exists (204 feet) to the north. But in the north-east 750 feet is attained, and there are plane surfaces and deep ravines on the floor, which lead from the northern parts of the lake, and unite as they proceed southward, being separated by elevated tracts. It must be specially noticed that the shores to the south-east of the lake have drifts 130 feet deep on them.

Lake Erie, 563 feet above sea level, is a shallow lake, and has its bottom as nearly level as any terrestrial surface. For 156 miles from the western border its mean depth scarcely varies 72 feet; then there is an area 210 feet in depth, followed by shallower water, then a deeper channel is found, taking its course between Long Point and the exit of the lake in the Niagara River, that is, in a north-easterly direction.

Lake Ontario, 280 feet above sea level, is a broad, not very deep basin, with an escarpment at the western end and terraces between it and the shore. The floor of the lake slopes gradually down to the mean depth of 400 feet at the rate of 30 feet in the mile; then there is a deeper part of 540 feet, with a trough in it reaching down to 600 feet, and in some places to 738 feet. This is a long channel nearer the American shore than the Canadian, and it is from 3 to 12 miles in breadth. The study of the soundings indicates that the southern margin of Lake Ontario has a series of submerged terraces, and, in fact, if it could be lifted out of water, the landscape would present the terraced appearance of the Niagara side. Now, these submerged terraces are, of course, separated by escarpments, and thus the outline of the floor will be more or less stepped, and will show a great longitudinal chasm.

On land, on the Niagara side, east of Niagara, and corresponding to the position of the end of the deep channel of Lake Erie, remains of a vast cañon filled with drift, and 743 feet in average depth, have been found. That is to say, a deep and wide gorge, down which a river flowed, connected Erie and Ontario, and the floor of

the river in it was 180 feet *below* the present surface of Ontario. This gorge is filled with drift, and therefore was in being before the drift. It existed before Niagara River and Falls.

On mapping out the direction of the deep channels of Huron, Erie, and Ontario, it becomes tolerably evident that a deep valley in a rather flat country, assuming now and then the characters of a cañon, ran from Lake Huron through the land to Lake Erie, and from Lake Erie to Lake Ontario, and then along the American side of the latter.

Late researches have indicated that Lakes Michigan and Superior discharged towards the Mississippi, but the first entered Superior by an eastern cañon. But all these deep channels, cañons, and flat and sloping and rocky bottoms, belong to a system of drainage which existed *before* the age of the drift. The present drainage is the result of the blocking up of the former outlets by drift.*

Hence the great lakes were in existence before the glacial period, and the greater part of their fauna lived then, and the species have never become extinct.

Covered and nearly filled with ice during the severe winters, and crowded with icefloes and small bergs, the relics of the broken ends of the great glaciers which came down to and into the lakes for a certain distance, the lakes were yet never entirely filled with ice which could carve them out of the hard rocks of their area.

The only manner in which the present floors could have been made, was by subaerial erosion in preglacial times, and then were formed the valleys and cañons. The fauna existed then, and probably the sturgeon, salmon, and crustacea made their way from the sea along the outflowing river. Then came the subsidence which enabled the waters to collect, and finally to reach to 300 feet higher than now, and to cover the sloping lands by the sides of the long chasms. Subsequently the glacial period began, and ice reigned to a certain extent supreme. No sea reached the lakes, and they were not filled with drifts, but were carriers of some of it by their floating ice. Gradually upheaval commenced, and terrace after terrace was developed, and the present level at last was gained.

The theory of the subaerial denudation of the floors of these lakes

* Surveyed by Spencer.

appears to simplify the notions regarding the course of the contours of the great African lakes, and even of Baikal.

Time will not render it possible to do more than notice the fact that there are around and beyond the great American lakes, especially to the north-west, a great series of smaller ones.

The last lake to be mentioned in South America is Titicaca, 100 miles north of Arica on the western side of the continent, and it is the highest known lake of any very considerable dimensions. Placed on a table land of some breadth, and with hills in the distance, this large lake is 12,800 feet above sea level, and its greatest depth is 924 feet. Many parts are shallow and even swampy; there are islands also, and the whole area covered is 4,600 square miles. A small river issues from the lake to the south, and runs for 180 miles, and terminates in the Lago del Desaguero.

The lake is beyond all glacial action, and contains *Siluroid* and *Cyprinoid* fish, besides some very remarkable crustacea belonging to the Amphipod group and to the genus *Allorchestes*. These are remarkable for being small, many-legged things with one of the front claws greatly enlarged. Some are found at a depth of 396 feet in the lake, which is of fresh water. Now, these crustacea belong to a genus which is usually marine and found on the shore. But fresh water species are found in streams and by the side of still water all over the American continent.* The deep-dwelling species from Titicaca are examples, then, of a genus which is pre-eminently littoral. No fresh water forms of the genus are found in the Old World.

The principal interest, however, of this lake is, that there are indications of great upheaval of the country during the latest geological age. On the coast to the west of Titicaca, and distant 20 miles from the Pacific, corals were found attached to rocks under the great deposit of nitrates which is found there. They were from 2,500 to 3,000 feet above the level of the sea. They were not of ancient species, but belonged to the present day, and moreover a species of nullipore and a crustacean were found in a pool of salt water at about the same level. Saline deposits on the west slope of the Andes exist even to 7,000 feet, and all this evidence tends to prove, that within the days of the existing marine animals, the West Coast of South America

* Surveyed by A. Agassiz and De Pourtales.

has slowly risen from the waves, to its present grand development.

But even with this explanation of the present height of the lake, and the existence of its marine-looking crustacean fauna, the cause of the lake and its very considerable depth remain unexplained. It is situated in palæozoic rocks of carboniferous age, and there are at some distance, and at a height of 15,000 feet, extensive volcanic rocks. Subaerial erosion and volcanic undermining probably occurred before the subsidence which let the area below water and filled it, forming a deep sounding in the sea.

In concluding, it is necessary, briefly, to sum up the facts and arguments which have been brought to bear on the question of lakes. It is clear that these beauties of Nature have usually been associated with grand movements of the crust of the earth, with the subsidence and upheavals and curvings of the strata which have developed, at last, the present continental systems. Every great lake has had its floor eroded, in the first instance, by subaerial agents, and it formed then part of a tract of subaerial wear and tear. This erosion may have been intensified by movements such as curving, faulting, and local subsidences, until a district became lower than the neighbourhood. Subsequently the valley within or outside a mountain system, had its own watersheds, and was part of a hydrographical basin.

The next stage was one of partial subsidence, and greater or less intrusion of the sea, and then came participation in the continental movements which developed table lands and great anticlinals and synclinals; a great altitude being given to the lakes in the one instance, and a great depth of the bed in others, with diminution of breadth.

When within the influence of the glaciation of a mountain range, the lake being already formed, and in a line of drainage, it was in some instances a tract of floating ice carrying glacial *débris*, and as the land rose or the waters became less in the lake, this was deposited on its flanks and shallows.

There are good reasons for discrediting the hypothesis that the sea, or ice in the form of a glacier, can erode and wear out bottoms some hundreds of feet deep, and the remarkable fauna of some lakes gives them a certain geological age.

The impossibility of the introduction of such a fauna as that of the lakes of Geneva, Brientz, and of Northern Italy, of Baikal, Aral,

and Tanganyika, and the great American lakes by the accident of the carrying power of birds is tolerably certain. Migration from a watery source, over land, is impossible in the majority of the present lacustrine faunas, the fish with protected gills being alone capable of it.

It follows that the present faunas of lakes are the outcome of marine, brackish, and fresh water accessions during the mutations in the level of the surrounding areas.

ANNUAL GENERAL MEETING,

February 3, 1882.

W. H. Hudleston, Esq., M.A., F.G.S., President, in the Chair.

The following report was read :—

The Census of the Association on January 1st, 1882, was as follows :—

Honorary Members	15
Ordinary Members—	
a Life Members (Compounded)	85
b Old Country Members (5s. Annual Subscription)...	20
c Other Members (10s. Annual Subscription) ...	370
Total	490

Showing an increase of 34 Members for the year.

The Association has experienced very considerable losses by death during the past year. Allusion has already been made, at the meeting in March, to the death of Professor Tennant (see "Proceedings," vol. vii., p. 95), who was the third President of the Association (1862-1863), and whose services were so valuable in its earlier years. Under his auspices good work was done. Among the "Proceedings" and Papers of this period we find the following :—"On Ancient Flint Implements in Yorkshire," by

the Rev. Mr. Wiltshire; "On the Cretaceous Group in Norfolk," by Mr. Rose; "On Coal Plants," by Professor Morris; "On the Lead Mines of England," by Mr. Sopwith; "On the Strata Exposed by the Excavations for the Southern High Level Sewer," by Mr. Bott; and the "Visit to Herne Bay and Reculver," by Mr. Dowker. During this period excursions were frequent and well attended, one of the most interesting being that to the International Exhibition of 1862 (see "Proceedings," vol. i., p. 279).

In Mr. Charles Moore the Association loses an Honorary Member, who has ever welcomed them to Bath and the neighbourhood. In May, 1872, in conjunction with the Rev. Mr. Winwood, he directed a very successful excursion to Bath, which was rendered more interesting from his demonstration of the remarkable series of fossils, mostly of his own collecting, in the museum of that city. We again find Mr. Moore directing an excursion to Swindon in June, 1876, on which occasion he exhibited a remarkable series of small fossils from the Purbecks of that limited area. Again, in June, 1879, he was the sole director of a second excursion to Bath, when he drew particular attention to the wonderful series of remains from the Rhætic drifts of Holwell, with the neighbourhood of which he was quite familiar. No director of excursions was better acquainted with the West of England than Mr. Charles Moore.

The death of Sir Antonio Brady is very recent, he having attended the opening Meeting of the present session. His public spirit is well known to all, so that almost every institution, likely to do good, came in for a share of his favour, ours amongst the number. In conjunction with Dr. Henry Woodward, he directed an excursion to Ilford in June, 1871, and afterwards exhibited at his own house that wonderful collection of mammalian remains which has subsequently been transferred to the British Museum. On that occasion the Members were also hospitably entertained by him. Since that time Sir Antonio Brady has perhaps paid less attention to Geology than to other branches of natural science, yet he was a member of your Committee as recently as 1878, and always evinced an interest in the affairs of the Association.

Your Committee have again the pleasure of offering their congratulations on the good financial position of the Association, as shown by the Balance Sheet. In accordance with your recommendation at the last Annual Meeting, a sum of £60 has been

expended in the purchase of Government Stock, by which the amount of Consols now held by the Association has been brought up to £399 10s. 3d. Another similar investment will accomplish what has long been desired, the equalization of your funded property with the amount of the compositions of all the Life Members of the Association. Your Committee therefore recommend that £50 be this year invested.

The balance would have been considerably reduced by a Committee vote to contribute to the Building Fund of University College, had not your President generously given to that fund £20, which he desired might be considered to be in place of the proposed contribution from the funds of the Association.

Vol. vii. of the "Proceedings" has been commenced, and the series of papers published therein maintains the importance which they have hitherto had, especially in the fact of their having largely had reference to the localities of the excursions, though general questions have had their due share of attention.

The Library still continues to be extensively used. Many donations have been received and a few purchases made during the past year, and some of our own Members have contributed their published papers. A considerable number of pamphlets have been bound, thus rendering them available for circulation.

The following is a list of the Museums and Geological Collections visited by the Association during the past year:—

British Museum, where Stuart D. Ridley, Esq., gave a demonstration on Recent Corals.

Museum of Practical Geology, Jermyn Street, where Frank Rutley, Esq., F.G.S., gave a demonstration on Rocks.

British Museum (Natural History), South Kensington, where Dr. Henry Woodward, F.R.S., F.G.S., conducted the Members over the Geological Galleries.

Blackmore Museum, Salisbury, where Dr. Blackmore gave a demonstration on the admirable Collection of Flint Implements and Mammalian Remains contained in that Museum.

Mr. Saunders' excellent Collection of the Fossils of the Neighbourhood of Luton.

Museum of the Keswick Literary and Philosophical Society.

Mr. W. Kinsey Dover's Collection of Skiddaw Fossils.

The following is a list of the Excursions—which, as usual, were

well attended—with the names of the Directors and the principal formations of each locality:—

LOCALITIES.	DIRECTORS.	PRINCIPAL FORMATIONS.
Salisbury and Vale of Wardour.	The President; John S. Phené, Esq., LL.D., F.G.S., &c.; Dr. H. P. Blackmore.	High and Low Level Gravels, Chalk, Greensand, Gault, Purbeck, Portland and Kimmeridge Clay.
Charlton, Blackheath, and Lewisham.	J. Logan Lobley, Esq., F.G.S., &c.	London Clay, Oldhaven Beds, Woolwich Beds, Thanet Sands, Chalk.
Croydon, Shirley, and Addington.	J. Flower, Esq., M.A., F.Z.S.; J. Logan Lobley, Esq., F.G.S.; H. M. Klaassen, Esq., F.G.S.	Oldhaven Beds, Woolwich and Reading Beds, Thanet Sands, and Chalk.
Grays.	Prof. J. Morris, M.A., F.G.S.; H. Walker, Esq., F.G.S.	High Level Gravels and Brick Earth, London Clay, Thanet Sands, and Chalk.
Sheppey.	J. S. Gardner, Esq., F.G.S.; W. H. Shrubsole, Esq., F.G.S.	Lower Bagshots and London Clay.
Isle of Wight.	E. B. Tawney, Esq., M.A., F.G.S.; F. G. H. Price, Esq., F.G.S.	High Level Gravels, Bembridge and Osborne Beds, Upper, Middle and Lower Headon Beds, Upper, Middle and Lower Bagshots, London Clay, Woolwich and Reading Beds, Chalk, Upper Greensand, Gault, Lower Greensand, Wealden Beds.
Higham.	W. Whitaker, Esq., B.A., F.G.S.	Drift, London Clay, Oldhaven Beds, Woolwich Beds, Thanet Beds, Chalk.
Luton.	Professor Morris, M.A., F.G.S.; Jas. Saunders, Esq.; J. Hopkinson, Esq., F.L.S., F.G.S.	Upper Chalk, Totternhoe Stone, Lower Chalk, and Chalk Marl.

LOCALITIES.	DIRECTORS.	PRINCIPAL FORMATIONS.
Lake District, Cumberland.	The President; Prof. J. Morris, M.A., F.G.S.; C. E. De Rance, Esq., F.G.S.; W. Kinsey Dover, Esq., F.G.S.	Glacial formations, Carboniferous Limestone, Silurians, Volcanic Series of Borrowdale, Skiddaw Slates, Syenite, Felsite Granite, Diabase.

The thanks of the Association are especially due to the following for assistance and hospitality at the Excursions:—The President; Dr. Blackmore; Mr. D. G. H. Gordon, F.G.S.; Mr. Brasher, Place House, Tisbury; Rev. Mr. Andrews, Teffont, Tisbury; Mr. Lilly, Tisbury; Mr. W. H. Jackson, F.G.S.; Mr. H. Johnson, Croydon; Mr. F. Banbury, Shirley House; the Archbishop of Canterbury; Mr. A. W. Channer; Mr. Easton, C.E., F.G.S.; Mr. Anson; Mr. Philcox; Mr. F. G. H. Price, F.G.S.; Mr. R. B. Grantham, M. Inst. C.E.; Mr. H. S. Freeman, Bembridge; Rev. C. H. Fielding, Higham; Mr. H. Russel, Cliffe; Mr. Henry Brown, Luton; Mr. Saunders, Luton; Mr. George Smith, Hundred of Hoo Railway; Mr. Shrubsole, F.G.S.; Mr. Wm. Topley, F.G.S.

The following is a list of the Papers read at the evening meetings, which have, as usual, been well attended:—

On the Zones of the Chalk, by Prof. MORRIS, M.A., F.G.S.

Remarks on Proposed Classification of Rocks, by Prof. T. G. BONNEY, F.R.S., &c.

On a New Theory of the Formation of Basalt, by Prof. T. G. BONNEY, F.R.S., &c.

Notes on the Microscopic Structure of the Basalt of Swallow Cliff and Uphill, by J. SLADE, Esq., F.G.S.

Note on a Mandible of Ischyodus Townsendii, found at Upway, Dorchester, in the Portland Oolite, by E. T. NEWTON, Esq., F.G.S.

On the Geology of Colorado, by S. R. PATTISON, Esq., F.G.S.

On Coniferæ, by J. S. GARDNER, Esq., F.G.S.

On a Continuous Section of the Oligocene from Headon Hill to Colwell Bay, by Prof. J. F. BLAKE, M.A., F.G.S.

On the Geology of the Vale of Wardour, by the PRESIDENT.

On the Geology of the Neighbourhood of Keswick, by the PRESIDENT.

On Graptolites, by J. HOPKINSON, Esq., F.G.S.

On Deep-Sea Investigation, by the PRESIDENT.

On the Lower Palæozoic Rocks, by Dr. H. HICKS, F.G.S.

Your Committee have to announce with regret the retirement—occasioned by other pressing duties—of Mr. B. B. Woodward from

the office of Librarian, which he has filled since 1878 with great advantage to the Association, and especially will his tenure of office be remembered by the excellent catalogue of the books which he has made.

Your Committee have much pleasure in proposing Mr. Litchfield as the future Librarian. Mr. Litchfield is not a stranger to the duties of the office, since, for some years he has very zealously assisted your former Librarians, thus giving a guarantee of the interest he takes in the work, and placing the Association under much obligation to him. Your thanks are due to Mr. F. J. Rowbotham for valuable assistance in connection with the Library.

Your thanks are still due to the Council of University College for continuing their liberality in allowing us the use of their Library for our monthly meetings. Your thanks are also due to the Quekett Microscopical Club for the continued use of their lamps at our annual meeting.

The Report of the General Committee was unanimously adopted as the Annual Report of the Association for the year 1881.

The following officers and General Committee for the year 1882 were then elected:—

PRESIDENT.

W. H. Hudleston, Esq., M.A., F.G.S., F.C.S.

VICE-PRESIDENTS.

Prof. T. Rupert Jones, F.R.S., F.G.S., &c.
Henry Woodward, Esq., LL.D., F.G.S., F.R.S., &c.
Jas. Parker, Esq., M.A., F.G.S.
J. Hopkinson, Esq., F.G.S., F.L.S., &c.

TREASURER.

J. Logan Lobley, Esq., F.G.S., F.R.G.S.

SECRETARY.

J. Foulerton, M.D., F.G.S.

EDITOR.

Prof. J. F. Blake, M.A., F.G.S.

LIBRARIAN.

Ed. Litchfield, Esq.

GENERAL COMMITTEE.

Wm. Carruthers, Esq., F.R.S., F.G.S., F.L.S.
E. Swain, Esq., F.G.S.
R. W. Cheadle, Esq., F.G.S.
John Bradford, Esq.
W. J. Spratling, Esq., B.Sc. Lond., F.G.S.
J. Drew, Esq., M.D., F.G.S.
W. Fawcett, Esq., B.Sc.
F. W. Rudler, Esq., F.G.S., M.A.I.
H. Hicks, Esq., M.D., F.G.S.
H. M. Klaassen, Esq., F.G.S.
Prof. John Morris, M.A., F.G.S., &c.
B. B. Woodward, Esq., F.G.S.

GEOLOGISTS' ASSOCIATION.

Balance Sheet for the Year ending December 31st, 1881.

Dr.

		£ s. d.
To Balance, January 1st, 1881		138 17 6
„ Life Compositions		36 15 0
„ Admission Fees	£21 10 0	
„ Annual Subscriptions	£125 0 0	
		146 10 0
„ January Dividends on £340 17s. 8d. Consols	£4 19 4	
„ July Dividends on £399 10s. 3d. Consols...	£5 17 5	
		10 16 9
„ Sale of Publications		12 9 11
		£345 9 2

Cr.

	£ s. d.
By Printing and Illustrating "Proceedings"...	92 19 7
„ Miscellaneous Printing...	32 18 8
„ Posting and Addressing	34 10 11
„ Library	14 4 2
„ Fire Insurance on Stock of Publications ...	1 17 6
„ Stationery	2 16 10
„ Gas, Attendance, and Sundries	13 1 8
„ Purchase of Consols and Brokerage	60 0 0
Balance	92 19 10
	£345 9 2

We this day having examined the Accounts of the Geologists' Association, find the above Statement to be correct, and that a balance of £92 19s. 10d. remains in the hands of the Treasurer.

S. R. PATTISON, }
W. B. GIBBS, } Auditors.

January 24th, 1882.

The thanks of the Association were given to the retiring officers, and the meeting then terminated.

ORDINARY MEETING,

FEBRUARY 3, 1882.

W. H. HUDLESTON, Esq., M.A., F.G.S., President, in the Chair.

The list of donations to the library since the last meeting was read, and the thanks of the Association were returned to the donors.

The following was elected a member of the Association :—Peter Forbes, Esq.

The meeting then resolved itself into a conversazione.

[redacted]

ORDINARY MEETING.—Friday, March 3, 1882.

W. H. Hudleston, Esq., M.A., F.G.S., President, in the Chair.

The donations to the Library since the last meeting were announced, and the thanks of the Association returned to the Donors.

The following were elected members of the Association :—W. Atkinson, Esq., Rev. Geo. Bailey, Lieut. G. A. Cole, R.N., Thos. Davies, Esq., F.G.S., G. W. Godwin, Esq., F.S.A., Wm. Maggs, Esq., L.D.S., and W. A. Prout, Esq.

The following papers were then read :—

1. The Progress and Prospects of English Submarine Tunnels.

By C. E. de Rance, F.G.S., F.R.G.S., Assoc. Inst. C.E. of H.M.'s Geol. Survey.

A correct knowledge of the conditions under which water flows underground is an all-important factor in ascertaining how far it may be practicable to tunnel under arms of the seas, and wide and important rivers. All fresh water, whether at the surface, or percolating into the ground, is derived from the rain, the amount absorbed being governed by the depth of the annual rainfall, the extent of the superficial area and vertical thickness of the absorbent rocks, and the varying degree of their porosity, increasing with the open character of the rock from a pint and a half of water to the cubic foot in granite, to two gallons in a cubic foot of soft chalk. The water stored in the spaces between the solid grains of porous rocks, flows under the influence of gravity down the dip planes of the strata, and is supported by the first impermeable material that may underlie the porous rock, which latter becomes fully saturated and incapable of absorbing any further quantity of the daily rainfall. The water absorbed having been taken in at higher levels, flows out under pressure when intercepted either by natural divisional planes in the strata formed by lines of faults and by joints, or by artesian well borings. In either case the water rises to a height dependent on the difference in elevation of the level of the point where it is absorbed and where it is delivered, but diminished by friction against the material

through which it has travelled. When the actual outcrop of a porous bed occurs under water, the outflow of the fresh water contained within the rock absorbed in inland areas, and issuing under pressure, will be still further retarded by the weight of the column of water resting upon it; where the level of the absorption area is but slightly above the sea-level the column of water absorbed by the land exposure of the porous rock will exactly balance the column of water resting upon an equal area of its submarine exposure, and no water will issue as land springs in the sea or river bed; and no water will percolate into the rock, which is already saturated.

Mersey Tunnel.—At Neston, in Cheshire, colliery workings have been carried more than three-quarters of a mile under the Dee, but no percolation from the river takes place, the whole of the water daily pumped being derived from land absorption. The same facts are observable on the Welsh side of the Dee, where extensive colliery workings under the sea exist at the Mostyn and Bettisfield Collieries. The rocks here dip at a high angle in the direction of the Dee, and consist of beds of impermeable shale alternating with sandstones, which absorb water freely. It is from these that the water pumped is derived, and none can possibly come from the bed of estuary of the Dee, unless the workings should be carried so high that the roof gives way, or, in driving towards the centre of the river, porous sandstones should be met with that have their *only* outcrop in the bed of the estuary. It is not likely that the rate at which such rocks can absorb water will be more than half a million gallons per square mile daily, so that supposing the find of water encountered by a tunnel traversing them to be derived from an area extending a mile and a half on either side, the water to be contended with would amount to a million and a half gallons per day for each mile traversed.

Nowhere, perhaps, are the actual conditions connected with the underground flow of water better known than at Liverpool and Birkenhead, on the opposite sides of the Mersey, under which a tunnel is now in course of construction. Five public wells in the New Red Sandstone in the Birkenhead district connected with the Wirral waterworks together yield from 3 to 5 million gallons a day; the deepest descends to a depth of 657 feet below Ordnance datum; the water is pumped down about 50 feet, being 14 feet

above O.D. at Prenton, and 30 feet below it at Wallasey. Five public wells at Liverpool yield about $6\frac{1}{2}$ million gallons a day, the Green-Lane-well individually having yielded as much as $3\frac{1}{2}$ million gallons daily. At Dudlow Lane the water is pumped down 86 feet, the pumping level of most of them being about 40 feet below O.D. The area pumped down by a well may be compared to an inverted cone, of which the apex is determined by the position in which the pumps are placed; if the yield diminishes through overpumping, the point of suction has to be lowered, so as to secure a broader base to the cone, giving an extended gathering ground. In none of the wells giving public supplies at Liverpool or Birkenhead has the *area of exhaustion* reached the margin of the coast, but near it shallow wells are effected by the tides, proving that percolation from the river only takes place in that portion of the sandstone rocks which lies *between* tide marks. Below low-water mark, the rock being already fully charged, no percolation takes place.

Several schemes have from time to time been mooted for tunnelling under the Mersey; the present undertaking now being carried out lies between the St. George's Landing Stage at Liverpool and the Landing Stage at Birkenhead, a distance of three-quarters of a mile. A shaft has been sunk near the former, at the bottom of Church street, commencing at 21 feet above Ordnance datum, and descending to 159 feet below it, or 180 feet from the surface.

A similar shaft has been carried out on the Cheshire shore, commencing at 25 feet above Ordnance datum, and descending to 143 feet beneath it, or 168 feet from the surface; from the bottom of these shafts headings, or small tunnels, are being driven to meet, steadily rising towards the centre to a level of 128 feet below Ordnance datum, which will be that of the rails of the permanent tunnel. This will gradually descend through tunnels in Lancashire and Cheshire, the rail level intercepting the Birkenhead shaft at 85 feet from the surface, and the Liverpool shaft at 86 feet. The lowest point of the railway tunnel corresponds to the summit of the heading or drainage tunnel, the idea being that the water being permanently pumped at a lower level than the rails, the railway tunnel will be effectually kept clear of water.

The explosive used in the work is chiefly dynamite jelly, fired

with a fuse. The explosives are stored in a magazine at Fazakerley, on a hill above Liverpool, the quantity of explosives used amounting to 100lbs. a day.

The quantity of water at present pumped from the Liverpool shaft, and the heading from it 100 yards in length, is 2,500 gallons per minute, and from the Birkenhead shaft, and the heading from it 350 yards in length, of which 60 yards is under the Mersey, 2,000 gallons per minute, the quantity of water increasing in proportion to the surface exposed, the total quantity pumped giving a daily average at Liverpool of 3,600,000 gallons, and at Birkenhead 2,880,000, while the combined pumping capacity provided gives 13,500,000 gallons per day, which is greater than that of the present public wells.

Taking the greatest depth of the river at about 70 feet at low tide, the average sectional area of rock lying between the level of the bottom of the shafts and the bed of the river will be 45 yards; supposing the area of supply to extend a mile on either side of the tunnel, this submarine area would occupy about a square mile and a half. From experiments which have been conducted to ascertain the capacity of the Pebble Beds of the New Red Sandstone for absorbing water, it appears they take up 0·73 of a gallon to a cubic foot, or nearly 62 million gallons to a square mile, one yard thick, so that before any percolation from the Mersey could take place, no less than 4,185 million gallons would have to be pumped, which, with the maximum pumping power would take nearly a year to execute.

Supposing this area exhausted of water by pumping down to a depth of 160 feet below Ordnance datum, and percolation from the bed of the river to ensue, it would probably take place at the following rate. The greatest depth of the river is 70 feet, and the average depth may be taken at 40 feet, which would give a pressure of about 17½ pounds to each square inch of sandstone exposed. Experience has shown that with a pressure of 20lbs. to the square inch, the percolation in these sandstones amounts to 7½ gallons per hour per square foot of surface.

The average percolation under the bed of the Mersey may therefore be taken at 6 gallons per square foot per hour, or 144 gallons per day, or for the area of absorption affecting the tunnel, a daily intake of 110½ million gallons per day, but the resistance offered

by the particles of rock through which the water would have to pass would reduce this quantity to about 4 gallons per hour, or 96 gallons per day, or 64 million gallons for the entire area.

A careful examination of the surface of the ground in the north of England discloses the interesting fact that the present configuration does not always precisely correspond with that of the harder rocks, on which rest the sands, gravels, and clays which form so large a part of the actual surface of the ground in the northern and north-midland counties.

These superficial deposits were laid down during the Glacial episode in our climate, and since the appearance of the existing species of mollusca, whose shells are daily thrown up on our coasts, and they not only fill up many of the deeper valleys, and overspread the plains to a depth of nearly 200 feet, but rise on the slopes of the hill-sides to an elevation of 1,200 feet. For the most part the existing lines of drainage follow their pre-glacial predecessors, and the action of running water has scooped out a new valley in the Drift, on the line of the older one, and the phenomenon called "valley within valley" is observable, numerous examples of which occur on the Lancashire slope of the Pennine watershed, and on the coast of Northern Yorkshire, where the bottom of the old pre-glacial valley is often 100 feet below the sea level, pointing to the land being, at the very least, 100 feet lower in regard to the sea-level than it was before the Glacial submergence.

Many of the valleys of West Lancashire have been entirely excavated out of Glacial Drift, the rock being only visible in the bed of the stream. The valley of the Ribble, at Preston, is a good example of this, the whole of the valley, 180 feet in depth, and nearly two miles in width, having been excavated by the Ribble since the deposition of the Upper Boulder Clay, the latest of the Glacial Deposits.

The bottom of this Post-Glacial Valley at Preston is about two feet below high-water mark, and following the river towards the sea, the level of the rock is found to gradually descend seawards, and where the Glacial Deposits have been denuded away, to be overlaid by river gravels, pre-glacial sands, and peaty beds, deposited upon the rock when the land stood somewhat higher than at present, and the river had consequently a longer fall to the sea.

In the low-lying country between the Ribble and the Mersey,

there exists to some extent a gauge indicating what this difference of level was, for at the Palace Hotel, Southport, the peaty beds have been found at a depth of 77 feet below high-water mark, or about 60 feet below the mean level of the sea, pointing to a submergence of the land of at least 80 feet since the present valley of the Ribble was formed.

In the Towell valley similar phenomena are observable between Manchester and Flixton, and in the Mersey valley between Stockport and Warrington, these rivers flowing at the bottom of a wide valley excavated entirely in Glacial Drift deposits, more or less concealed at the sides by terraces of alluvium left by the river when it flowed at higher elevations. The rock is only seen here and there in the bed of the river, and before reaching Warrington it disappears beneath it, descending to a depth of 87 feet beneath the Ordnance datum near the bridge, to 100 feet at Sankey Bridge, reappearing at the surface at Runcorn Gap. But at Widnes, immediately to the north, it descends to a depth of no less than 176 feet below Ordnance datum, the whole of the intervening space being filled up with Glacial Drift, chiefly consisting of compact Boulder Clay.

The Runcorn Gap gorge or valley is the Post-glacial outlet of the river, which in pre-glacial times ran over the site of the modern town of Widnes, as has been pointed out by Mr. Mellard Reade. Westward and seaward from this depression no such great depth to the rock has been recorded, and there is some probability that this part of the bed of the river is below the former position of the slope to the sea, and that it marks the site of an old lake. On the Cheshire side of the river "the valley within valley" is well seen at Runcorn in the valley of the Mersey, and at Frodsham in that of the Weaver.

Westward the rock appears at several points on the banks of the Mersey, occasionally rising into cliffs, as at Ince, Eartham, and Broomborough, and Tranmere Ferry; between these points the surface of the rock dips below the river level, and the Glacial Drift fills up the depression, the depth of which in some instances must be considerable, as in a boring at Horton, two miles inland, the rock was not reached until a depth of 65 feet was reached; and in several wells at Birkenhead, near Wallasey, the drift was not penetrated until 115 feet below Ordnance datum. On the

opposite side of Wallasey Pool, at the pumping station, rock occurs at 70 feet below the Ordnance datum. At Leasowe Castle the rock is said not to have been reached until 180 feet, but there is no doubt that in this case the soft Kemper Marls were mistaken for Boulder Clay.

The Wallasey Pool valley in pre-glacial times was occupied by a stream flowing south-east into the Mersey, but the valley was wider than at present, and was at least 120 feet deeper, the land standing that amount higher above the sea than at present.

The Horton boring indicates a valley excavated by a stream that must have flowed into the pre-glacial Mersey, and its depth gives some clue to the depth of the valley into which it fell at its outlet, which must of necessity have been greater, or something between the 60 feet found in its tributary stream and the 115 feet north of Birkenhead.

On the Lancashire side of the river borings have proved that the rock at Ditton iron-works, and from Hale by Speke Hall to Garston, is beneath the sea-level at high tides; at the latter place it is eight feet above O.D. on the sea margin, and crops to the surface in the Dingle.

Westward to Dingle Point the rock forms the base of the Glacial Drift, which here thins off, and the Mottled Sandstone forms a picturesque cliff; still further westward a tract of alluvium lies at the bottom of the slope on which Liverpool is built, resting on Boulder Clay, but occasionally lying directly on the rock, which has been well seen in the foundation of the wonderful chain of docks fringing the coast line.

The depth of the channel of the Mersey increases from 27 feet at the low water of an equinoctial spring tide off Garston to 63 feet close to Dingle Point; off Rock Ferry the deepest point is only 50 feet, off Tranmere 60 feet, over the line of the projected tunnel only 57 feet; off Eysemont the depth is 64 feet; off New Brighton 70 feet. The Ordnance datum, or mean level of the sea at Liverpool is 4·75 feet *above* the Old Dock Sill, and 14·75 feet above the level of low water at the equinoctial spring tides, which is the datum on the Admiralty charts for the depth of the above soundings, so that the greatest depth of the bottom of the Mersey over the proposed tunnel is 71·75 feet below Ordnance datum, and lowest point at which, putting together all the evidence, there is

any likelihood of the bottom of the pre-glacial valley being met with, is about 110 feet below the datum.

There appears to be little doubt that the remainder of the tunnel will be as successfully carried out as the present distance excavated. When completed it will be of sufficient size to accommodate two lines of rails, and will be entirely bricked round, and rendered effectually watertight.

Observations are now being taken by the engineers of the Liverpool Corporation at Runcorn Gap, where it is proposed to carry a tunnel under the Mersey for the reception of the pipes conveying the waters of the Vyrnwy to Liverpool. The river here is 350 yards broad, and consists of the New Red Sandstone, which, the borings prove, has been furrowed in pre-glacial times, and the hollows filled in with Glacial Drift.

Channel Tunnel.—To those who have not studied the geology of the south-east of England, it may appear somewhat remarkable that the advocates of the scheme of the Submarine Continental Railway Company should state that though the grey chalk will be found to be perfectly dry, the white chalk will be found to be heavily charged with water, requiring constant pumping. But this apparent anomaly disappears when it is known that the geological horizon, called by the East Kent people "Grey Chalk," is the formation so well known in Sussex and Hants by the name of the *Chalk Marl,* long since described by Dr. Mantell, and still longer ago in that much-read book White's "Selborne," where its great fertility when decomposed into "white malm" is discoursed on, and its value for hop and wheat-growing purposes is shewn.

The chalk marl of East Kent differs in no respect from the chalk marl of other parts of the country in being practically waterless, and being the nearly impermeable material that supports the wonderful supplies of water given by the white chalk in many areas, as in that pumped by the Kent waterworks, east of London, which raise about 10 million gallons daily, and could easily double that quantity, while the chalk marl in deep borings at many localities has been found to be absolutely waterless, as at Kentish Town, Harwich, Southampton, Calais, and in the Belgium and French coalfields, where its impermeable character keeps out the water of the fully charged white chalk from the coal-workings beneath.

Between Folkestone and Dover the various subdivisions of the cretaceous series dip steadily to the north-north-east, and the cliffs of East Weir Bay, Abbots, and Shakespeare's Cliffs, terminate a plateau ranging from 400 to 500 feet above the sea, scattered over which are farms with wells sunk through the white chalk to the chalk marl, which supports the water absorbed by the white chalk; this issues in a strong spring called the Lydden Spout, formerly used to drive a mill for the manufacture of whitening, and also, I believe, for the locomotives of the South-Eastern Kailway.

That the grey chalk or chalk marl is continuous from England to France there can be no doubt, but that its "strike" or direction is constant is another matter; in any case the tunnel advocated by Sir Edward Watkin would be driven dry from both sides for a considerable distance, and should a fault be intercepted, or flexures in the bedding bring in the white, porous chalk for a portion of the distance, it will simply be a question of additional cost for pumping and secure lining of the tunnel, for the Upper Green Sand below the chalk marl and the white chalk above it are both porous, and therefore charged with fresh water absorbed on the land; and as it is a physical necessity that a porous rock fully charged with water is incapable of receiving any more, it follows that porous rocks beneath the sea connected with the land are incapable of absorbing water from the sea itself, unless the permanent fresh-water level should be artificially lowered by abstracting more fresh water than can be naturally replaced from the land, which latter condition has occurred at Calais, where a brackish spring occurred at 70 feet from the surface, and at Liverpool, where wells close to the docks have become brackish through overpumping, while wells in the sea, as those off Spithead, moderately pumped give perfectly fresh water. Should the tunnel intercept porous rocks, the area to be drained to carry out the work would probably be a square mile on either side of the heading, which would together yield about a million gallons of water per day.

The cliffs at Lydden Spout were measured by Mr. F. G. Hilton Price and myself in 1876, and were described by Mr. Price in a paper on "The Beds between the Gault and Upper Chalk near Folkestone."* The height at this point was found to be 433 feet above the mean sea-level, and the thickness between the Upper Gault and first bed of flints (Upper Chalk) to be 348 feet.

* 'Quart. Jour. Geol. Soc.," Vol. xxxiii., p. 431.

Of this thickness the Lower White Chalk forms the upper 150 feet; the upper part of this is the *Craie marneuse*, and the lower part the *Craie noduleuse* à I. labiatus of Dr. Barrois; the whole belongs to the Turonien of D'Orbigny; the lower 32 feet is the zone of *Cardiaster pygmæus* of Mr. Price, and is the "grit bed" of local geologists, from its hardness being sufficient to turn the point of a pick-axe; the mass of the bed is made of comminuted fragments of *Inoceramus* and other fossils. The overlying bed is soft, but is not of so pure a white colour as the Upper Chalk; water can freely percolate through it, but it is doubtful whether much can pass through the underlying "Grit bed." Beneath is the junction bed, or zone of *Belemnite plenus* of Mr. Price, 4 feet in thickness; it is of soft texture, of a dark yellowish colour, and porous character. Below the junction bed is the Grey Chalk, 169 feet 9 inches thick; the upper 55 feet is the zone of *Belemnites plenus* of Dr. Barrois; the lower 93 feet is the *Craie argileuse* avec bancs chefs à *Ammonites rhotomagensis*. The next two feet nine inches is the well-marked "cast-bed," which is marked and striped with mottlings of a darker colour; it contains a remarkable assemblage of fossils, which have somewhat of a Gault facies, and it essentially marks the horizon of springs in the area through which it runs and issues, and it is from this that the Lydden Spout itself is supplied. Below the "cast-bed" is 19 feet of marly chalk forming the zones of *Ammonites rhotomagensis* and *Am. varians* of Dr. Barrois. Beneath the marly beds forming the base of the "Grey chalk" is the Chloritic, or rather Glauconitic marl. It is traversed by hard reefs of sponges, which are occasionally converted into iron-pyrites, and are more or less entangled with the bones of *Ichthyosaurus*; it is the *Craie marneuse à Plocoscyphia mœandrina* of Dr. Barrois.

At Copt Point the Chloritic marl rests upon more sandy beds, which have been believed to represent the Upper Greensand of more western areas, but according to Mr. Price and Dr. Barrois, the fauna it contains does not correspond to that of the Upper Greensand of the west of England, but is essentially a part of the fauna of the Chalk Marl, and Mr. Price regards these sandy beds as the base of the Chalk Marl, and calls it the zone of *Stauronema Carteri*; it is the equivalent of the zone of *Pecten asper* of Dr. Barrois, and of the Warminster Beds.

The following table gives the classification of the Kentish chalk

adopted by various observers in relation to their French equivalents :—

D'Orbigny.	Drew in Geol. Surv. Memoir.	Dr. Barrois.	F. G. H. Price, Q.J.G.S., Aug., 1877.		
					Upper Chalk.
Turonien.	Concretionary (?) nodular chalk, 73 feet	Craie marneuse	IX.	Lower Chalk with Inoceramus labiatus.	Echinoconus subrotundus and Terebratulina gracilis, 118 feet.
			VIII.		Cardiaster pygmæus, 32 feet (Grit bed).
Cenomanien.	Soft bed of 6ft. with Belemnites	Craie compacte à *Bel. plenus*	VII.	Grey Chalk.	Belemnites plenus, 4 feet.
		Craie argileuse avec bancs chefs à *A. rhotomagensis*	VI.		Holaster subglobosus, 148 feet.
	White Chalk without flints		V.		Cast bed 2ft. 9in.
			IV.		Am. rhotomagensis, 11ft.
		Zone à *Am. varians*	III.		Am. rhot. and Am. varians, 8½ft.
	Chalk Marl, say 30 feet	Craie marneuse à P. mæandrina.	II.	Chalk Marl.	Zone of Plocoscyphia mæandrina, 10 feet.
		Marne sableuse à Pecten asper	I.		Zone of Stauronema Carteri, 14 feet.
					Upper Gault.

Sheet 1 of the topographical map of France contains much information bearing on the proposed tunnels; the map contains the Kentish coast from Dymchurch to Sandwich, and the French coast from Sangatte to Calais. Its scale is $\frac{1}{80000}$, or about two kilometres to the inch. The map was constructed by officers of the Corps d'Etat Major, and was published in 1832 by the War Department. In 1875 and 1876 the French frontier and the English coast between Eastweir and St. Margaret's Bays were geologically surveyed by M. Potier, and the results published by M. Jacquot, Inspector General of Mines, and Director of the Detailed Geological Map of France, the divisions adopted below the alluvium being the White Chalk, the Craie Marneuse, the Craie de Rouen, and the Gault. These subdivisions were also traced under the waters of the Channel by M. Levalley, M. Larousse, and MM. Potier and de Lapparent, and the results incorporated in the map. The investigation was made for the Association for Submarine Railways between France and England; 7,671 soundings were taken, and 3,267 specimens of the bottom brought up, which were identified, or believed to be identified, with the formations named, proving an absolute continuity of the formations exposed on either side of the Channel under the bed of the sea, the subdivisions extending from France across the Channel with a uniform W.N.W. direction until within a few miles of the English coast, when an anticlinal fold, running parallel to the coast, throws the various outcrops a few miles northward. A similar north-east anticlinal fold occurs parallel with the French coast, but much closer to the shore, and the curve is of less vertical range, the horizontal displacement of the beds being proportionately less.

The map also contains three lines showing the position of the outcrop of the upper surface of the Gault under the underlying rocks, at depths respectively of 50, 100, and 150 metres below low-water mark; these lines, being practically subterranean contours, constitute the map a longitudinal section in all directions, the upper surface of the Gault being represented as descending from low-water mark in Eastweir Bay to 50 metres beneath that level off Shakespeare's Cliff, to 100 metres off Dover Castle, to 150 metres off St. Margaret's Bay. The latter depth, 492 feet, is checked by a boring put down at St. Margaret's Bay by Sir John Hawkshaw, in which the upper chalk was passed through to a depth of 249 feet; the lower or grey chalk, which consisted largely

of marl, was found to be 296 feet thick, the Upper Greensand three feet, and the Gault was penetrated to a depth of 19 feet, the total depth reached being 567 feet, which gives 548 feet from the surface; the boring was probably carried out at or but little above high-water mark, as the first nine feet passed through was shingle; the range of the tides here is about 18 feet, so that the proved depth of the surface of the Gault is 530 feet below low-water mark, or 32 feet more than is indicated by the underground contour. On the opposite coast an artesian well at Ostend reached Palæozoic slate rock at 300 metres; the cretaceous strata overlying it were only 302 feet thick, of which the first two-thirds were pure white chalk, the lower parts marls; the Palæozoic floor here is about 980 feet below the sea-level.

A boring made at Hames-Bucre, near Guisnes, 6½ miles south of Calais, proved the Palæozoics to be only 669 feet beneath the surface, and consequently still less below the sea-level.

	FEET.
Vegetable earth...	6·56
White chalk with flints	347·68
Grey chalk	282·08
Green Sand and black clay (Gault)...	32·80
Red Schists	6·56
	675·68

It will be noted that the chalk proved at Ostend and Guisnes shows a steady thickening towards the south-west, the grey chalk at the latter place being nearly as thick as the whole of the chalk at Ostend. The Lower White Chalk without flints of Folkestone appears to be absent in both the St. Margaret's Bay and Guisnes borings; light is thrown upon this absence by the unsuccessful boring for water at Calais, of which a careful record has been preserved by Mr. E. Blakeway and by Prof. Prestwich from specimens preserved in the Calais Museum.

BEDS.		METRES	= FEET.
1 to 22	Alluvial soil, London Clay, and Thanet sands	72·95	
23 to 27	White and Grey Chalk with flints ...	128·95	... 422·95
28 to 40	Hard Grey Chalk and Chalk Marl ...	104·29	... 342·07
41 to 45	Upper Greensand and Gault	8·70	
46 to 47	Lower Greensand and Palæozoic (carboniferous) beds...	30·17	
		345·06	

From this section it appears that only the first 91 metres of chalk were white, the remainder of the flint-bearing chalk being marly and grey-coloured; a spring of water was met with at 160 metres, but was brackish, and did not rise to the surface; the horizon at which it occurred would be at the base of the white beds, four and a half metres above the grey; all the beds are thicker than at Guisnes, showing that the beds are thinning towards the Carboniferous ridge to the south, as well as towards the east.

In the boring about three miles west of Calais, in the direction of Sangatte—communicated by Sir John Hawkshaw to Professor Prestwich—the following beds were passed through:—

BEDS.		FEET.
1 to 7	Alluvium and Drift ...	70
8 to 10	White chalk	197
11 to 16	Grey chalk	284
		551

This boring probably reached the base of the grey chalk, but the evidence is not quite conclusive that it did so.

Still further west are the two shafts put down by the French Association at Sangatte for the purpose of investigating the actual condition of the base of the Rouen chalk as regards its suitability for the purposes of making the proposed Channel tunnel. The results obtained by these works were described to the French Academy in June last by M. Daubrée, who stated that the shafts were 86 metres (282 feet) in depth, one of them being 5·40 m. in diameter; the white chalk and the upper part of the Rouen chalk were found to be water-bearing; the base of the latter chalk was found to allow but little water to pass; the water met with was perfectly fresh, except quite near the surface, where veins of slightly salt water occurred; the upper surface of the gault was found in the shaft at 59 m. ($193\frac{1}{2}$ feet) below the hydrographic zero (low-water mark) adopted in the French Government Geological Map containing the investigations of 1875-6 referred to above. M. Daubrée states that though the water met with was fresh, it was directly affected by the tides, increasing in volume with high tides, and decreasing with its ebb; a tunnel has been driven seawards in a north-westerly direction, about seven feet above the upper surface of the gault. The water met with here is said not to exceed 80 gallons per minute.

The deepest portion of the Straits of Dover is a long, narrow trough running about N. 30 E., with a remarkable uniformity of direction, passing on the east or French side of the Colbart and Varne ridges, between Cape Gris Nez and Folkestone, and also on the east side of the Goodwin Sands; thence it stretches away to the North Sea, its width gradually narrowing, being affected by the entrance of the waters of the Thames and its tributaries, which have silted up the Essex coast. The depth of this trough varies from 20 to 35 fathoms, the deepest part being immediately south of the line of the proposed tunnel, which crosses the trough, where the deepest water is about 31 fathoms, or 186 feet below low-water mark.

The depth of water at low tide over the Varne is only nine feet and over part of Colbart ridge but little more. The Goodwin Sands rise above the low tide level, but over the lines of the projected tunnel there is no trace of shallow water, the tunnels by both schemes crossing north of the Varne and south of the Goodwins.

Several alternative routes have been suggested for piercing the ground beneath the Channel. Prof. Prestwich suggested the Palæozoic rocks, from their complete impermeability to water; the late M. Thomé de Gamond suggested one intersecting various formations from Cape Gris Nez to Eastweir Bay; Mr. Low and Sir John Hawkshaw from a point near the South Foreland to a point near Sangatte. Of the schemes now before Parliament, one supported by Sir John Hawkshaw proposes to start near his original point of departure, viz., at Fair Hole, 2½ miles from Biggin street, Dover, where the proposed tunnel will be approached by a descending gradient of 1 in 80, penetrating the northern ridge of the Castle Hill; the tunnel would become submarine at a depth of 115 feet beneath high-water mark at spring tide. The tunnel, if carried out, would penetrate the white chalk for a considerable distance. It is probable that Sir John Hawkshaw intends to carry his tunnel in a straight line to join the existing works at Sangatte. This direction will be slightly oblique to the strike of the beds; consequently as the tunnel advances it will pass into lower beds and eventually into the grey chalk in which the French works are being carried out. The larger quantity of water which would be met with in the first half of a tunnel constructed on this line of route would gradually diminish as the grey chalk was entered, but it is in the highest degree probable that the water held by a square mile of

chalk on either side of each mile of tunnel driven from the English shore would have to be contended with in the construction of the first ten miles, or two million gallons of water per mile; but this quantity would not be cumulative.

In the tunnel projected by the Channel Tunnel Company, intersecting Dover, and carried beneath its fortifications, the submarine portion will be in the porous white chalk, and wholly beneath the level of permanent water in it; and it may be fairly assumed that every mile driven will add a million gallons of water to be pumped; the total sum, if abstracted at both ends, is not an impracticable one to deal with, but the abstraction increases the cost of the work, not only by the expense of lifting this amount of water, but by the consequent necessity of lining the tunnel, and moreover deprives the inhabitants and garrison of Dover of their water supply.

The northern shaft is situated on the Folkestone side of Shakespeare's Cliff; it is 160 feet in depth, boarded at the sides; the bottom reaches the grey chalk, and terminates in a square chamber, from which runs a circular tunnel seven feet in diameter, traversed by a double line of tram rails. The shaft first penetrates 40 feet of debris, the result of the blasting operations some years ago; below this is the base of the white chalk resting on the grey; the sea-level occurs at 60 feet below the surface, and the tunnel at 100 feet below the surface of the sea; the latter has now been driven three-quarters of a mile in the direction of the Admiralty Pier, Dover, with a diameter of seven feet, but eventually this will be enlarged to 14 feet, by cutting an annular space of three and a half feet around it, the second hole, like the first, being cut by machinery driven by compressed air, and requiring the attention of only two men. The length of the Beaumont machine is about 33 feet. The work is done by the cutting action of short steel bits, placed in two revolving arms, each containing seven bits, which advance 5-16ths of an inch with every complete revolution, with two to three revolutions per minute, the progress being at present 100 yards a week, or three miles a year. Colonel Beaumont anticipates, however, a future progress of 3-8ths of an inch per revolution, with five revolutions per minute. The compressed air leaves the reservoir at the pit mouth with a pressure of 35lbs., which is reduced, after passage through 1,250 yards of four-inch iron pipe, to 20lbs., but it is thought the loss would be rendered less by doubling the diameter of the pipes.

The submarine portion of the tunnel would be 22 miles, with four miles of approaches on either side, the English approach starting from the western end of Abbott's Cliff tunnel, from which half a mile of heading has been driven.

The gradient would be 1 in 80 towards Dover and the centre of the Channel until a depth of 150 feet below the bottom of the sea is reached, after which it would be driven approximately level, rising slightly towards the centre to throw off the water on either side should it be met with. The tunnel would be lined with cement made with grey chalk derived from the tunnel itself, mixed with pebbles from Dungeness.

The new heading in the chalk at Shakespeare's Cliff for the proposed Channel tunnel has now been carried a quarter of a mile, and is being carried on at an average of 36 feet per day, 80 men being in all employed in two shifts, and a third more will shortly be employed. The excavations are now many yards under the sea in the direction of the Admiralty Pier at Dover; the workings are quite dry, the springs which caused so much delay in the former experimental heading at Abbot's Cliff being absent. The present rate of working, if carried on at both ends, would give eight years for completion of the tunnel and connection with the railway systems of France, which would be reduced by working 24 hours a day.

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2. Description of a Section across the River Severn based upon the Borings and Excavations made for the Severn Tunnel.

By Evan D. Jones,* of Severn Flint Works.

The portion of the Severn Basin here described is entirely hidden beneath a considerable depth of Alluvium at one end, and forms the bed of the Estuary at the other. Until the borings and excavations for a tunnel underneath the river were recently carried out, but little was known of it.

The new section by which this is illustrated is seven miles in length, between Almondsbury Hill, in Gloucestershire, and the banks of the river, in Monmouthshire. At its western extremity it lies beneath the river, which is here 2¼ miles wide, and at its

* I am indebted to Charles Richardson, Esq., C.E., Engineer of the Severn Tunnel Works, for his kind permission to use the information contained in the documents and sections in his office.

eastern end beneath the alluvial flats, which have here a width of 3½ miles.

The tunnel now being constructed runs under the river and a portion of the alluvium along the line of section. Its position is indicated in Figs. 2 and 3. A great many borings were put down along its whole length, several shafts sunk and headings driven all the way under the river, with the exception of about 130 yards near the English shore. Other headings have also been driven along the land portion of the tunnel from each of the shafts, affording information from which a geological section across the whole width of the Severn Basin can be constructed.

At high water the whole of the 2¼ miles forming the bed of the river here are covered, there being a depth of water at the shallowest place of 24 feet at spring tides, and of 13 feet at neap tides; but at low water the rocks over the greater part of this distance are exposed, those on the English side stretching out for 1½ miles, with the exception of a narrow strip of water left by the tide, about 150 yards wide, immediately adjoining the English shore. These rocks are called the English Stones, and are composed of New Red Sandstone. On the Welsh side also the rocks of the bed of the river are exposed at low water, and have, as on the English side, a strip of water separating them from the shore. The low water rocks on this side are called the Lady Bench and the Lower Bench. Between these rocks and the English stones is the actual river channel, called the "Shoots," through which the whole of the water runs at low tide. This channel is 450 yards wide at the top, and 280 at the bottom, with a depth of from 50 to 55 feet, and the slopes of its sides are very steep, that nearest the Welsh shore, where the curve is convex, being almost perpendicular. The course of the river is shown on the map (Fig. 2), where it will be seen that after leaving the "Shoots" the deep water channel runs towards the English shore, forming at Avonmouth the deep water anchorage of Kingroad. The "Shoots" and the rocks on either side are shown in section in Fig. 3, and it will be observed how deep and narrow the "Shoots" are when compared with the whole bed of the river.

From some thousands of soundings which were taken near this section and in other places, under the direction of Mr. Richardson, the deeper parts of the floor were found to be comparatively level, and a boring put down on its eastern edge proves that very nearly the whole of the rock through which it passes is Pennant Grit

Fig. 2. Map of Severn Basin & Adjoining Country.
Scale 2 Miles – 1 inch.

Fig. 4. Sections of Shafts.
Scale 50 Feet – 1 inch.

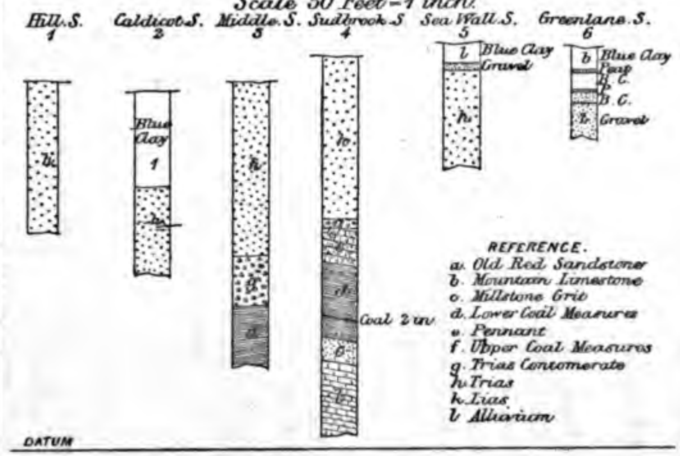


Fig. 3.
Section from Almondsbury to Portskewet.
Horizontal Scale 1000 yds – 1 inch
Vertical " 100 " – 1 "

of the very hardest description, with a few feet of New Red Sandstone on the top.

Two theories have been advanced to account for the formation of this channel. The first, advocated by the late Mr. Stoddart, asserts it to be an ancient fissure which existed here prior to the time when the river commenced to run; the second, advocated by Mr. Richardson, attributes its existence solely to the action of the river itself, which, by the wear and tear of ages, has worn it away to its present dimensions, and is still engaged in widening and deepening it.

If the first theory had been correct, the strata on either side would have been found to incline in opposite directions from the axis of upheaval, and we should have also expected to find the bottom of the fissure filled up with debris ; but on the contrary, in driving the heading underneath the channel, solid, compact Pennant Grit occurred, dipping regularly in one direction, without any evidence of dislocation.

In support of the denudation origin of the channel, it may be stated that the current here possesses extraordinary power, having on some occasions a speed exceeding 12 miles an hour. Large quantities of pebbles and gravel are carried backwards and forwards by it during spring tides. The following instances may be cited :—

1. When the piers for the Bristol and South Wales Union Railway were being built excavations had to be made in order to receive the brickwork footings; the excavations had to be made during the low water of one tide, and the brickwork put in during the low water of the next, and it was found that during the one flow which intervened the holes had become full of pebbles and gravel.

2. The fishermen here, who are in the habit of making holes in the rock to receive poles for fastening their nets to, find that if these holes are left for a few tides, before putting the poles in, they become so completely choked with pebbles and gravel, which are jammed in so tight, that they sometimes find it easier to dig new holes than to reopen the old ones.

3. In driving underneath the English Stones, about half-way along, a fissure was met with which can also be traced on the surface of the Stones, and although it was about two feet wide, the pebbles and gravel had so effectually choked it up that not a drop of river water came from above into the heading.

It must be remembered that these effects are to be seen above low water mark, and near the shore, where the current is but weak compared with that in the " Shoots," along the bottom of which the great bulk of the gravel must be rolled.

Owing to the curved form of the channel, the current acts with much greater force upon the Welsh side of the " Shoots," which is consequently worn steeper and deeper than the other, as is clearly shown in section (Fig. 3).*

The fact of the low water channel being so narrow here, and the rock so strong, render this place the best possible for crossing the river by means of a tunnel, as only a quarter of a mile will thus be constantly under water.

Altogether 10 shafts have been sunk for the construction of the works, 3 on the English side and 7 on the Welsh; but it will only be necessary to describe six of these, as the remaining four are sunk respectively alongside of Nos. 3, 4, and 5, one each side of Nos. 3 and 5 and two by the side of No. 4.

The direction of the line in which the headings have been driven is given in plan on Fig. 2, being represented by the thick dotted lines from A to C, which is the total length of the tunnel. It is shown in section by the dotted lines on Fig. 3.

The positions of the shafts are also indicated on these two figures. Fig. 4 shows a section of each of the six shafts driven in the line of the tunnel; they are arranged in order, and at their respective levels above a given datum.

Shaft No. 1 is about two miles in shore on the Welsh side, and is wholly in the New Red Sandstone. It is 75 feet deep. No. 2

* The following extract from a paper read by Mr. Richardson before the British Association at their Bristol meeting in 1875 places this matter in a very clear light:—

" It has only to be conceived that at the time when the Severn first began to run down this way, and before the banks or cliffs on each side had been worn back, the surface of the ground was undulating, as it is elsewhere. The river waters would, of course, follow the lowest natural channel that was to be found, and in this case that channel may have been narrow, and in the place where the " Shoots " are now found. The rise and fall of the tide being then, as now, very great, it would roll up and down this channel large quantities of gravel, and this gravel would gradually and constantly deepen the channel along the deeper parts of the course of the stream, so that, as the river was gradually widened by the action of the water alone on the sides, this original channel would still continue to be the deepest, and consequently the main pathway of the water-driven pebbles. . . . . The rate of wear must, however, have been very slow, for the hard rock has only been worn down to a depth of about 70 feet since the time when the river first ran this way; a rate of it may be less than a foot in ten thousand years.'

is sunk through the Marshland at Caldicott, one mile in shore from the Welsh Bank; one half of it is in Severn Alluvium, consisting of Blue Clay, and the other half in the New Red Sandstone. This shaft is 100 feet deep.* Shafts Nos. 3 and 4 will be fully dealt with further on. No. 5 is sunk immediately behind the Sea Wall on the English Bank of the river. It is 70 feet deep; the first 15 feet are in Alluvium, consisting of 12 feet of Blue Clay and 3 feet of gravel. The remaining 55 feet are in the New Red Sandstone. No. 6 is half a mile in shore from No. 5, and is entirely in Severn Alluvium. It is 45 feet deep, and the top of the New Red is immediately underneath. The first 30 feet of this shaft are in Blue Clay, containing two layers of Peat, each about two feet thick. A bed of gravel, 15 feet thick, formed the remainder of the shaft. It is stated by some of the inhabitants of this Marsh that the land is slowly sinking. If such is the case, it is probably due to the existence of these two layers of peat, which, under the weight of the overlying Clay, are gradually being compressed.

The high water of spring tides rises above the level of these Flat Marshlands, which has rendered it necessary to protect them by means of a sea-wall. Before this wall was built, some 45 years ago, the land was continually being flooded, but since its erection, which enabled the land to be properly drained and cultivated, the soil is considered to be one of the richest in the district.

Returning to Shaft No. 4, sunk at Sudbrook Point, on the Welsh Bank of the river, and 200 feet deep, the order of the strata is as follows:—Under the top soil was a thin bed of gravel, then a six feet bed of fine sand, and the remainder, to a depth of 85 feet, was New Red Sandstone, consisting of 13 feet of Yellow Sandstone, and 65 feet of very hard Marl. Three springs of water, yielding about 12,000, 27,000, and 15,000 gallons an hour respectively, were tapped in sinking through the Marl. Under the Marl came a bed of Dolomitic Conglomerate, four feet thick, of

* Several fresh water and marine shells were found in this Alluvium. The following is a list of those obtained at a depth of 39 feet below the surface, named by Professor Sollas, of University College, Bristol:—

Scrobicularia piperata	Cardium edule (not distorted)
Lymnea peregra	Planorbis glaber
„ auricularia	Hydrobia marginata ?

Specimens of some of these are preserved in the Bristol Museum.

Prof. Sollas also kindly examined a specimen of the Alluvium itself, which was found to contain—

Diatoms; grains of quartz; entomostraca (cypris, &c.); seeds and leaves of plants, especially of chara; sponge spicules (spongilla).

the same character as a thick bed of Conglomerate on the beach by the Portskewet Pier of the Bristol and South Wales Union Railway, and known locally as the "black rock."

This Conglomerate is also exposed for a distance of 300 feet at low water on the western edge of the "Shoots." From the frequency with which it has been met with in sinking in various places, and the number of places in which it is exposed along the beach, and at low water on the bed of the river, it appears to extend over a considerable area in this district, and possesses such prominent characters that it deserves to be particularly noticed. Its thickness varies considerably, being in some places as much as 28 feet, whilst in others it thins out to a mere strip, disappearing in some places altogether.

In sinking two shafts (represented by No. 3 in section, Fig. 4) about a quarter of a mile in shore from the one under notice, and which are only 45 feet apart from centre to centre, it was also met with, being in the one shaft 28 feet thick, and in the other 24 feet. In the latter it was divided through its whole depth by a joint about six inches wide, through which a large quantity of water kept constantly gushing in, whilst in the adjoining shaft it was perfectly compact and dry, and was so hard that the rate of sinking through it averaged only 1½ feet per day. The bed consists of limestone pebbles imbedded in a very hard reddish matrix, and in situ presents a very massive and solid appearance. Many of the pebbles are two feet in diameter, others not more than half an inch, and there are all sizes between. They vary considerably in form, some being more or less spherical, some oval, a few conical or egg-shaped; some have two flattened faces, others only one. One was nearly a perfect cone, rounded almost as regularly and smoothly as if by the hands of a lapidary, its length being 18 inches, and its greatest breadth nine inches. A portion of one of these pebbles, on being treated with dilute nitric acid, dissolved very slowly, and yielded a residue of microscopic crystals of dolomite, hæmatite, tourmaline, and quartz.

It was observed by Prof. Sollas* that most of the pebbles are marked by very characteristic striæ. These striæ are mostly about half an inch in length, commencing with a mere scratch, gradually deepening into a rut, and terminating in a little round pit, giving them much the form of a comet; they occur generally only on one

* "Geol. Mag.," February, 1882.

face of the pebble, and have their deeper ends all pointing in the same direction. Judging from the large quantity of quartz which the matrix has been found to contain, there must have been a considerable quantity of this mineral near at hand, and its crystals may probably have been the instruments employed in scratching the pebbles. But whether this be so or not, it is evident from the form of the markings, the gradual deepening of the ruts, and the character of their terminations, that the action took place when the pebbles were in motion, and that this motion was one which took place under great pressure. Further evidence of pressure is afforded by some of the larger pebbles, on which smaller ones adhere so firmly without any obvious cementing matter that it requires a hard blow from a hammer to separate them, and it is then found that they had penetrated in some cases about $\frac{1}{16}$ inch into the larger pebbles, leaving, when removed, a very decided impression of their form.*

The Coal Measures were entered under the Triassic Conglomerate, and the information on this point, afforded by the excavations for the Severn Tunnel, is that to which the greatest interest attaches. The Pennant Grit passed through, under the Conglomerate in this Shaft, had a vertical thickness of 19 feet, dipping towards the centre of the river, or a few degrees S. of E. at about 1 in 12, its upper surface here forming the plain of denudation upon which the Trias has been deposited. Beneath the Grit were 35 feet of the Lower Coal Measures, dipping in the same direction, 25 feet consisting of Clay Shales, and 10 feet of Coal Shales, separated by a 2-inch seam of coal. These rested on Millstone Grit, 11 feet thick, under which were interlaminated beds of Firestone and Shale, about six feet thick. Under the Shale came a remarkable bed made up of lumps of Mountain Limestone, with angular corners, imbedded in Shale, 14 feet in thickness; the lumps varied in size from small pieces to blocks as large as a wheelbarrow. The remaining 26 feet of the shaft penetrated a very hard, close-grained red firestone, or ironstone (as it was called by the miners), occurring in regular beds from 6 to 12 inches thick, separated by layers of hard fireclay about an inch in thickness.

From this Shaft two headings have been driven under the river,

* Prof. Hughes, in a paper read before the Geol. and Polytechnic Soc. of the W. Riding, Yorks (July 17th, 1867), has suggested that the striæ on the pebbles of Old Red Sandstone may have been formed in a similar way to that described by Prof. Sollas in the case of these Triassic Stones, and not, as Prof. Ramsay suggested, by glacial action.

[redacted]

a lower one commencing at the bottom of the Shaft, and an upper one 40 feet from the bottom, the former being continuous, and nearly two miles long.

The upper heading begins in the Millstone Grit, and the floor of the heading continues in it for 50 yards, but the roof passes into the Coal Shales at a distance of 10 yards. The length of Coal Shales passed through was 20 yards, and it was followed by the Shales for a length of 110 yards, when the Pennant was entered.

In the lower heading the same kind of rock that occurred at the bottom of the shaft was found for a distance of 40 yards, when the limestone blocks in shale were reached. The limestone was here continued for 90 yards, occurring first in strips about three feet thick (of which there were six interlaminated with shales), but becoming more massive towards the end, where a block about 12 yards thick at the bottom and tapering away to a point at the top was met with, which appeared to be but a projection of the limestone underneath into the overlying shales.

The next 40 yards were in the bed of shale which was found under the Millstone Grit in the shaft, and were followed by 40 yards of Millstone Grit, 30 yards of Coal Shales, and 70 yards of Clay Shales, the two latter representing the Lower Coal Measures. Resting upon these, the Pennant was again entered. It extended in one solid mass (with the exception of a few beds of interlaminated clay shales) for nearly a mile, carrying the heading about 500 yards beyond the Shoots channel. A considerable quantity of water was met with in various places in driving through it, about 150,000 gallons an hour altogether. The Upper Coal Measures were next entered, and were found to consist mainly of hard Clay Shales. In the portion immediately overlying the Pennant two seams of good hard coal were struck, one 15 inches and the other 10 inches in thickness. Some thin beds of Pennant were also found in this shale. The heading continued in these Upper Coal Measures for about 400 yards, when a sudden change took place, and the New Red Sandstone, which is here faulted down against the Coal Measures, was entered. Near to the fault, which is about half-way across the river, the strata were very much distorted, and no regular bedding was found for some distance. The rock contained veins of iron ore, and was perforated here and there by small pot-holes.

About 50 yards from the fault in the New Red Sandstone, a fissure was met with just large enough to admit of a man pushing

himself in. It can be traced at low water on the bed of the river immediately above, having a S.W. direction. The whole of the remainder of the heading driven in this direction, as well as that driven to meet it from the English side, is in the New Red Sandstone; and with the exception of that driven East from No. 3, which is in the Lower Coal Measures and Millstone Grit, all the headings which have been driven East and West from the other shafts, are in the same formation, and possess no features worthy of notice.

Shaft No. 3 is 150 feet deep, and goes down to the Lower Coal Measures only; the strata passed through correspond in order to No. 4, but, as stated above, the Conglomerate is here 28 feet thick, whilst the vertical thickness of the Pennant is only four feet.

Appended is a tabular list of the strata passed through in Shafts Nos. 3 and 4, and the heading from the latter driven East, which are the most important parts of the work geologically considered :—

	Shaft No. 3.	FT.
	Fine Sand and Gravel	18
Trias.	Yellow Sandstone	12
Trias.	Red Marl (very hard)	68
Trias.	Dolomitic Conglomerate	28
Carboniferous.	Pennant Grit	4
Carboniferous.	Lower Coal Measures (Clay and Coal-Shales Mixed)	20
		150

	Shaft No. 4.		FT.
	Fine Sand and Gravel		7
Trias.	Yellow Sandstone		13
Trias.	Red Marl (very hard)		65
Trias.	Dolomitic Conglomerate		4
Carboniferous.	Pennant Grit		19
		Ft.	
Carboniferous.	Lower Coal Measures	Clay-Shales 25 Coal-Shales 10	35
Carboniferous.	Millstone Grit		11
Carboniferous.	Shales (very hard)...		6
Carboniferous.	Limestone and Shales		14
Carboniferous.	Red Sandstone (hard and close-grained)...		26
			200

BOTTOM HEADING (from Shaft No. 4).

			YDS.
Carboniferous.	Red Sandstone (same as in bottom of Shafts)		40
	Limestone and Shales		90
	Shales		40
	Millstone Grit		40
	Lower Coal Measures	YDS. Coal-Shales 30 Clay-Shales 70	100
	Pennant Grit		1,600
	Upper Coal Measures (broken by Fault)...		400
Trias.	(all beyond the Fault)		

The first feature to be noticed in connection with these excavations is the great variety of strata which have been met with, and their perfect geological sequence. This is shown in a striking manner in Shaft No. 4. This Shaft is only 200 feet deep; nevertheless, in sinking through that distance, the New Red Sandstone, Dolomitic Conglomerate, Pennant Grit, Lower Coal Measures, and Millstone Grit occurred within a vertical depth of 154 feet.

The vertical thickness of the Pennant Grit here is 19 feet, as stated, its dip averaging 4·75°, and its horizontal length 1,600 yards. Calculating from these data, its actual thickness may be stated as 400 feet, or less than a fourth of its average thickness in the Bristol Coal Fields; but the greatest anomaly is in the thickness of the Lower Coal Measures and the Millstone Grit, which here have an actual thickness of only 35 feet and 11 feet respectively, as against 2,000 and 1,000 feet in the Bristol Coal Fields.

In the Cutting near Portskewet station on the South Wales Railway, nearly half a mile to the North West of the shaft, the Mountain Limestone is exposed, coming very nearly to the surface, dipping E.S.E., or nearly in the direction of the Shaft, at an angle of about 5°. From this it would appear that the Limestone ought to be found at the Shaft at a depth of about 200 feet from the surface. Very nearly at this depth the peculiar lumps of Limestone in shale, and the interlaminated beds of Limestone and Shale, were found, which show that in all probability we are there on top of the Mountain Limestone.

NOTE.—The average dip of the Carboniferous beds, ascertained by observations taken in the Shafts and Headings, and by comparisons of the relative positions of the beds in the Shaft with those in the headings, is about 4·75°, corresponding to a fall of 1 in 12.

It may be mentioned, with regard to the bed of Millstone Grit, that the distinctive character of the rock would leave no doubt as to its identity, even if this could not be established independently by its position.

From the distinctive character of the rocks, together with the regular sequence in which they occur, and the proximity of the outcrop of the Mountain Limestone in the vicinity, we are led to believe that the Lower Coal Measures and Millstone Grit thin out in this district to a mere strip, notwithstanding that they attain greater thickness in the Bristol Coal Fields.

We know precisely where the bottom of the Pennant is; we have every reason to believe that 50 feet lower down we are on the top of the Mountain Limestone, so that the Lower Coal Measures and Millstone Grit must be wholly contained in the intervening space.

The mixed beds of Shale, Limestone, and Sandstone which occur at the bottom of Shaft No. 4, and probably also for a short distance lower down, might be added to the Millstone Grit, thus increasing the thickness of the series to that extent, but as thin beds of Millstone Grit are usually found among the top beds of the Upper Limestone Shales, I have included this portion of the shaft in the Limestone series.

As far as can be ascertained, the actual thicknesses of the strata on the Western Side of the River Severn are as follows:—

	FT.
Trias	85
Upper Coal Measures (unknown) ...	—
Pennant Grit	400
Lower Coal Measures	35
Millstone Grit	11

These excavations give a considerable amount of information concerning the Coal Field known to exist under the Severn and adjoining Flats. The existence of this Coal Field was first proved by Mr. Richardson, C.E., 20 years ago, when constructing the Bristol and South Wales Union Railway. At that time about 50 tons of coal were obtained immediately beneath the surface from the excavations for the Calybrook Brick Works, and when tested the coal was found to be of exceedingly good quality, considering it was found so near the surface. It had many of

the qualities of the best coal, and was remarkably free from dust.

The width of the Coal Field in the district under notice is $5\frac{1}{2}$ miles, but it probably widens out considerably further south, passing under the alluvium around Avonmouth and Portishead, and terminating somewhere near the latter place; but nothing definite can be stated as to its actual limits at either this or at its northern end.

About two or three miles north of a line drawn from Portskewet to Almondsbury the Old Red Sandstone crops up on both sides at some little distance from the banks of the river, but gradually gets nearer further North, until, at a point 12 miles up, it completely hems in this portion of the Severn Basin, the river channel being there cut entirely through the Old Red. It is evident then that it cannot extend to the north much beyond Aust Cliff, where the masses of Mountain Limestone on both sides of the river must nearly approach each other.

VISIT TO THE BRITISH MUSEUM (SOUTH KENSINGTON).

SATURDAY, MARCH 11TH.

Director—T. FLETCHER, Esq., M.A., F.G.S., Keeper of the Mineralogical Collection.

DEMONSTRATION ON THE COLLECTION OF METEORITES.

The Director, before proceeding to indicate any particular specimens of Meteorites, gave a short sketch of the history of the subject, dwelling especially upon the reluctance even of scientific men, down to the latter part of the last century, to admit that these bodies had an extra-terrestrial origin. The connection between "sky stones" and "fire balls" was ultimately established about the end of the last, or commencement of the present century. Since then many falls have been observed, and the phenomena carefully investigated. Meteorites fall at all times of the day and night, at all seasons of the year, and favour no particular latitudes; moreover, they are quite independent of the weather. The origin of these foreign bodies is not yet clear, and many speculations have been hazarded, such as that they come from the volcanoes of the moon,

or that they are portions of a lost satellite of the earth, or are due to a collision of two planets. It is more probable that their origin must be sought in interstellar space, and, if at any time a real connection can be traced between meteorites and shooting-stars, this might go some way towards a solution of the problem.

Allusion was then made to some of the phenomena attendant on these falls, and the varying velocities of the bodies themselves: the reduction of speed and consequent friction, the resulting fusion of the surface, the shattering of the more stony masses, and their spreading in fragments over elliptical areas. Yet in spite of the surface generation of heat from friction, meteorites like that of Dhurmsala are sometimes so cold that they can scarcely be handled at first.

The composition of meteorites was briefly alluded to. Twenty-four of the commonest elements of the earth's crust have as yet been recognised, the most frequent being Iron, Magnesium, Silicon, Oxygen, and Sulphur.* All of these are met with in the combined state, but some, such as Iron, Carbon, and Sulphur, are present also in the elementary condition. Of compounds new to terrestrial mineralogy, the most important is Troilite, or Ferrous Sulphide, which is not far from magnetic pyrites. The terrestrial minerals which occur in meteorites are magnetite, chromite, tin oxide, varieties of olivine, bronzite, enstatite, augite, and anorthite.

The meteorites have been divided into (1) *Siderites*, or "sky-irons," (2) *Siderolites*, or the "sky-iron-stones," (3) *Aerolites*, or "sky-stones." In *Siderites* the iron varies from 80 to 95 per cent., the nickel from 6 to 10 per cent.: the nickel is partly alloyed with the iron. Troilite occurs in veins or large nodules in these sky-irons, sometimes in connection with graphite, with iron carbide, and with compounds peculiar to meteorites. The gases, hydrogen, nitrogen, and the oxides of carbon, have been found occluded in the iron. In *Siderolites* and *Aerolites* the minerals forming the stony part are almost entirely crystalline, and mostly in a "chondritic" or granular condition. They are such as characterise the more basic rocks. The most common type of stony meteorite has a crust which is black and dull. The fracture is grey, and rough to the touch, presenting a fine-grained matrix which consists of

* Mr. Heinrich Hansoldt has recently discovered (Journal Quekett Club, March, 1882) a meteorite, said to have fallen near Braunfels, in Germany, which is full of fluid cavities, containing, as he believes, liquid carbonic acid; the silicate resembling Phenacite. Hence we must add Glucinum to the list of elements.

nickel-iron, troilite, chromite, a soluble silicate (olivine), and an insoluble silicate approaching augite or enstatite; through this matrix are disseminated "chondra" or little spheres consisting principally of the insoluble silicate. There are also carbonaceous meteorites, which, besides the above, enclose sulphur, carbon, and hydrocarbons; such meteorites have been saved from combustion by the rapidity with which a crust has formed upon them in their passage through the earth's atmosphere.

The Director then pointed out several specimens of meteorites, or of fragments of well-known and historic meteorites, in illustration of his remarks. The sky-irons, such as that of Cranbourne for instance, which was found near Melbourne, Australia, in 1861, attain to a much greater size than the more fragmentary sky-stones, this one itself weighing several tons. On the other hand the largest sky-stone known is that of Knyahinya, weighing 647lbs. A small portion is preserved in this collection, the bulk being in the Vienna Museum.

The President, in thanking the Director for his instructive demonstration, referred to the exceeding richness of the meteorite collection, and to the fact that Prof. Maskelyne, ably assisted by Dr. Flight, had made the study of these bodies one of his especial occupations. The joint work of those two gentlemen—essentially British Museum work—had contributed largely to our knowledge, and it was satisfactory to find that Mr. Maskelyne's successor had already given an indication of his interest in the subject by the publication of a most valuable "Guide to the Collection of Meteorites," now in the hands of many of the members present. The subject was one well worthy of the attention of geologists. As the chemist avails himself of spectrum analysis to study the nature and composition of extra-terrestrial bodies, so, in like manner, when an extra-terrestrial body pays us a visit, we geologists should welcome the occasion as affording an opportunity for instruction with respect to the possible composition of the interior of our planet. One of the most interesting and instructive facts in this connection is the abundance of the magnesian silicates, olivine and bronzite-enstatite in these meteorites, and the considerable degree of analogy in the mineral constitution of the more stony of these bodies with such terrestrial rocks as lherzolite, olivinites, &c., facts largely insisted upon by Daubrée in the second part of his "Etudes synthétiques de géologie expérimentale."

VISIT TO THE BRITISH MUSEUM (SOUTH KENSINGTON), BOTANICAL DEPARTMENT

MARCH 25TH, 1882.

Director :—W. CARRUTHERS, ESQ., F.R.S., Keeper of the Department.

(*Report by* W. FAWCETT, Esq., B. Sc., F.L.S.)

On the 25th March, about 70 members assembled at the Natural History Museum, and were conducted over the Botanical Department by the Keeper, Mr. Carruthers.

Attention was first directed to the progress that had been made in the Exhibition Room. In the centre of the room are three lofty cases containing stems of trees and ferns, too large for the side cases. Beginning at the left-hand side, amongst the Dicotyledonous stems were noticed the Banyan, Cork Oak, Ebony, Clematis, Great Nettle Tree of Australia (*Laportea*), Hercules' Club, and the Paddle Wood of Guiana (*Aspidosperma*) ; in the second case, among the Monocotyledons, are the Betel Palm (*Areca*), Palmyra Palm, Sago Palm; in the third, the Wax Palm, Cocoa Nut Palm, Double Cocoa Nut or Seychelles Palm, Grass Gum Tree, Bamboo, and Vellosia. Returning on the other side, amongst the Gymnosperms are the anomalous Welwitschia, sections of Araucaria, pieces of Cedar of Lebanon, 3,000 years old, found by Layard in the Palace of Nimroud. In the same case are stems of Cycads, specially interesting to geologists in relation to the vegetation of Mesozoic times, the forms found in Portland Quarries being commonly known as Fossil Birds' Nests. In the next two cases are placed stems of Tree Ferns, such as Dicksonia and Alsophila. Mr. Carruthers drew particular attention to a longitudinal section of a stem of *Cyathea Dregei*, which exhibited the leaf scars at the base arranged spirally, and in the main portion in linear series, combining in the same stem the characters on which the genera Lepidodendron and Sigillaria, from the Palæozoic strata, have been separated.

In the cases projecting from the walls, a systematic arrangement of the Vegetable Kingdom is presented, following the order of the Natural System as generally adopted, beginning with the Ranunculaceæ and ending with Fungi. These cases are not yet completed, but enough had been done to show the general plan. Each Natural Order will be illustrated by specimens of plants with

fruits and woods; diagrams of remarkable plants, and of peculiarities of structure showing the main points that separate the Order from others; and by a table and map exhibiting the geological and geographical distribution of the Order, and when there is occasion for it, of important genera and species.

Amongst the Palms there is a fine series of Fossil Palms, many beautiful and instructive specimens from Antigua ; in the same case are the Nipadites, fruits from the London Clay, which can be easily compared with their modern representatives; and placed in the doorway of the case, there is a large and perfect leaf of Phœnicites, found in the Eocene Clay at Bournemouth by Mr. Starkie Gardiner.

After inspecting the Exhibition Room, members were invited into the Inner Room, set apart for the use of scientific botanists, when Mr. Carruthers showed how the plants are arranged in cabinets according to their Orders, Genera, and Species. This, the Great Herbarium, is intended not only to contain specimens of the various species, but also to illustrate their geographical distribution. It is based on the valuable Herbarium of Sir J. Banks, bequeathed to the Museum, and with this are incorporated several important collections, including those of Robert Brown, Nuttall, Gardner, Welwitsch, Miers, and Hampe. The collection of British plants is kept separate, in order to be more available to those who devote their attention particularly to the flora of the British Isles.

The recesses form convenient studies for botanists, and besides the tables in each recess, there will be placed cabinets for woods.

The cabinets in the centre of the room contain the collection of fruits and seeds, arranged in the same order as the Herbarium. In the Library, already very extensive, there is a large collection of drawings of plants, amongst which are the original drawings of Sowerby's "English Botany," and a magnificent series of original drawings of plants made by the brothers Bauer, L'Héritier, Ehret, Parkinson, and others.

The members of the Association examined some sections of fossil plants and fragments of the matrices from which they had been prepared. Special attention was drawn to some Lycopodiaceous Cones from the Coal Measures of Scotland, and to two important specimens of the same age found in France, the one described by Robert Brown as Triplosporites, containing only microspores, but perhaps only the apex of a cone, also exhibited, which was de-

scribed by Bronguiart and Schimper, containing microspores in the apex and macrospores at the base, and closely resembling, except in size, the cones of existing Selaginellas.

As the first Friday in April this year was Good Friday, no meeting of the Association was held.

EXCURSION TO BATTLE AND HASTINGS.

EASTER MONDAY AND TUESDAY, APRIL 10TH AND 11TH.

Directors:—WILLIAM TOPLEY, ESQ., F.G.S., Geological Survey of England and Wales; and J. E. H. PEYTON, ESQ., F.G.S., &c.

(*Report by* W. TOPLEY.)*

The chief geological interest of this excursion consisted in an examination of the lowest beds exposed in the Wealden Area. These, formerly known as Ashburnham Beds, but now called Purbeck, are exposed along a narrow line on the north and north-west of Battle. The lowest beds of the Fairlight Cliffs were also formerly called Ashburnham Beds, it being supposed that these and the beds near Battle were on the same geological horizon. Of the correctness of this determination there have always been grave doubts, and this is now known to be erroneous.

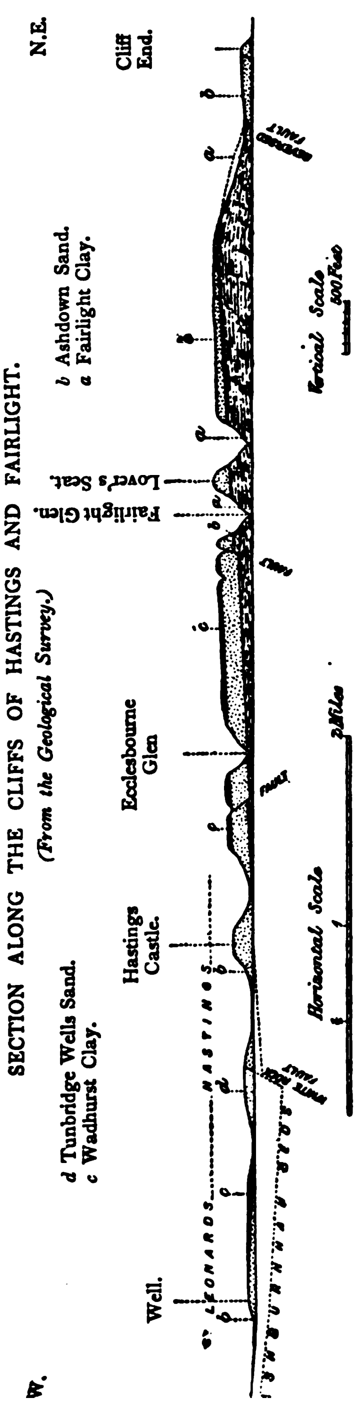
The highlands of the Wealden Area in East Sussex are formed of sand and sandstone (Ashdown Sand) brought up along anticlinal lines and by faults. This Ashdown Sand is probably 500 feet thick. Its lower part is clayey, and it is underlain (though generally with a faulted boundary) by the beds now known as Purbeck.

The cliffs of Fairlight, east of Hastings, expose a thickness of about 150 feet of sand and sandstone (Ashdown Sand); but below this there are 360 feet, with no base reached, of sand, sandstone, and mottled clay. These lower beds are now known as the Fairlight Clays; they represent the lower and more clayey part of the Ashdown Sand of inland areas. Without doubt they overlie the Purbeck Beds, which would probably be reached at a small depth only below the centre of the anticlinal at Fairlight.

* A notice of this excursion appears in the "Atlantic Monthly" for Sept., 1882, from the pen of M. D. Conway, who formed one of the party.

SECTION ALONG THE CLIFFS OF HASTINGS AND FAIRLIGHT.

(*From the Geological Survey.*)



The stratigraphical evidence for the succession as now adopted is, therefore, sufficiently strong. But the Sub-Wealden Boring has shown that the lowest beds of the inland area contain important beds of Gypsum, a mineral scarcely known in the Wealden Beds proper. Beneath them came the Portland Beds. Palæontologically also the revised reading is desirable, as estuarine shells frequently occur at various horizons in the Purbeck Beds, whilst the Wealden Beds of this area are characterized by fresh-water forms.

Monday.—The party assembled at Battle Station. The greater part travelled that morning from London, but were here joined by Mr. Peyton and others from Hastings.

After inspecting the ruins of Battle Abbey, the members drove northwards to the most easterly exposure of the Purbeck Beds, in Archer Wood. From thence a short walk brought them to the tramway from the Sub-Wealden Gypsum works, up which a journey was made in waggons. Three hundred years ago Sussex was a busy centre of the iron trade; but the mineral manufactures gradually declined, and during the last 30 or 40 years these have been almost limited to lime-burning. The discovery of Gypsum, however, which is

now being extensively worked, has once more placed Sussex in the list of mineral-producing counties.

The total thickness of the Sussex Purbecks is about 400 feet; 300 feet are exposed at various places; the lowest 100 feet or so are only known from the boring. Beds of limestone, once largely worked by means of pits, occur chiefly at two horizons, an upper one known as "The Greys" and a lower one called "The Blues." Below the Blues come other scattered bands of limestone, whilst lower still we have the shales with Gypsum. The Greys and the beds near them are usually very fossiliferous, the lower beds much less so.

The Sub-Wealden Boring was made during the years 1872-75, chiefly through the exertions of Mr. Henry Willett, of Brighton. A good selection of the cores, with illustrative sections, are placed in the Brighton Museum.

Prof. J. F. Blake suggests the following as a possible classification of the beds passed through in the boring:—

	Thickness. feet.	Depth from Surface. feet.
Purbeck	180	
Portlandian	60	... 204
Bolonian	660	... 900
Virgulian and Pterocian ...	430	... 1330
Astartian	30	... 1360
Supra-coralline	390	... 1750
Corallian	90	... 1830
Oxfordian	65	... 1905
	1905	

Tuesday.—This day was devoted to an examination of the cliffs east of Hastings. The cliffs are capped by Wadhurst Clay, near the base of which are bands of clay ironstone, and a shelly band of ironstone full of *Cyrena.* These beds were the chief source of the ore of the old Wealden Furnaces.

The top bed of the Ashdown Sand is massive, and forms natural rocks round the valleys. It is hard externally when weathered, but inside it is soft. St. Clement's caves at Hastings are excavated in this bed. A bed of shale, 30 feet below the top of the sands, makes a distinct feature in the cliff; it contains *Endogenites erosa.* Some interesting cases of extreme false-bedding were noticed. One of them, just east of Ecclesbourne, might be mistaken for evidence

of local unconformity between the Ashdown Sand and Fairlight Clays. The characteristic Mottled Clays of the Fairlight Clays appear in quantity near and east of Fairlight Glen.

A large groyne lately built east of Hastings intercepts the travel of shingle from west to east along the coast. The east end of the town has suffered much from the rapid removal of shingle and the wasting action of the sea.

VISIT TO THE BRITISH MUSEUM (SOUTH KENSINGTON).

Saturday, April 15th, 1882.

Director:—Professor R. Owen, C.B., F.R.S.

Demonstration of the Mammalian Fossils of South Africa and Australia.

No report of this visit has been received. The substance of the address delivered by the Director is contained in a paper read by him before the Royal Colonial Institute (May 6, 1879) "On the Extinct Animals of the Colonies of Great Britain," but the members had the advantage of seeing during their description the actual specimens referred to. The chief of these was the skull of the *Dicynodon*, showing the two large tusks from the upper jaw, while the lower jaw is edentulous, that of the *Ptychognathus* and other extinct reptiles of the order Anomodontia. After a series of Dinosaurs were shown the most remarkable forms of the Director's newer group of *Theriodontia*, with their three types of teeth, "incisors, canines, and molars." These are from the Cape. The chief Australian Mammals dealt with were the *Nototherium*, the *Diprotodon*, and the carnivorous *Thylacinus*.

ORDINARY MEETING.

FRIDAY, MAY 5TH, 1882.

W. H. HUDLESTON, ESQ., M.A., F.G.S., PRESIDENT, in the Chair.

The donations to the Library since the last meeting were announced, and the thanks of the Association returned to the donors.

The following paper was then read :—

ON THE GEOGRAPHICAL DISTRIBUTION OF CORALS.

BY STUART O. RIDLEY, M.A., F.L.S.

The Corals ought to be interesting above most other groups to a Geological Association from their ancient occurrence, the large extent to which their structures are capable of preservation in the fossil state, and their actual immense abundance in the seas of many past ages, placing them among the chief contributors to the rocks of the globe. In no country are these facts more prominently brought before our notice than in our own. The study of the Geographical Distribution of Corals is one which has found but few workers, and is at the present time rather behind that of the distribution of most other large groups of the Invertebrata. This is mainly due to the fact that very little has been done lately to incorporate the information acquired during the last twenty years with the results published by Esper in 1791-7, by Dana in 1839, by Darwin in 1842, by Milne-Edwards and Haime, 1857-60. Since these older writers, A. E. Verrill, of America, has done more than any one else to extend, systematize, and render precise our knowledge of their distribution, by his works on the Corals of the Atlantic and Pacific Oceans; but the information published by him is all contained in separate papers. Studer, a German naturalist, has done good service by his descriptions (1878-9) of the collections formed by a recent German circumnavigatory voyage, that of the "Gazelle." Up to Verrill's time, however, it was almost exclusively the *shallow* water which had yielded up its treasures to the explorer of the sea. M. and G. O. Sars, of Norway, had, indeed, brought up some strange and novel forms from considerable depths off the Norwegian coast from 1849 and onward, and the Bay of Biscay, the Shetland Seas,

and some other localities had been explored at depths beyond 200 fathoms, with success, but not in a manner sufficiently systematic to give a thorough insight into the fauna at abyssal depths. But in 1869-70 the vessels "Porcupine" and "Lightning" were despatched by our Government to explore the deep sea in the Atlantic, and series of soundings and dredgings were taken, giving results which leave no room for doubt as to the broad features of, at any rate, the Coral fauna at depths of 300 to 700 fathoms. Of these results, those embodied in Professor Duncan's report on the Corals are of the highest interest, no less to the palæontologist than to the zoologist, showing, as they do, the existence of links between the past and present races of Corals which had previously been unknown.

The younger Agassiz and Pourtalès in America have, during the last ten years, treated the West Indian seas in the same manner, and with results of similar import. Lastly, our own "Challenger" expedition, bringing material from a far larger area and from far greater depths than any previous deep-sea explorations, has, by the reports which it has enabled Professors Moseley (on the Deep-Sea Madrepores and some other groups) and Kölliker (in the *Pennatulida*, or Sea-pens) to produce already, both confirmed previous knowledge, and extended the depth-limits at which Zoophyte life was known to be possible, besides illustrating the ancient character of some of the groups and of individual species, and adding many striking new types to our lists.

In considering the subject of Distribution, I propose to treat of it under two heads, viz.: 1, The *Facts* of Distribution; and, 2, The *Causes* at work in producing the Distribution as we now see it.

I include under the term Corals on this occasion only those members of the three groups, ZOANTHARIA, ALAGONARIA, and HYDROCORALLINÆ, which secrete a calcareous skeleton, omitting from the second of these groups the *Pennatulidæ*, as being free-living organisms. For the definitions of the groups I must refer members to some remarks which I made on this subject before the Association on a former occasion. In the generalizations which are here formed as to the proportions in which groups are represented in certain localities, allowance must be made for the fact that it has been found impossible to embody every individual locality recorded for each species, but the general results may be taken as approximately correct.

In dealing with the first head the *Facts of Distribution*, I shall consider the Coral fauna of different marine districts in succession, and commence with (A) the ATLANTIC OCEAN, and in particular with its most northern division, the Arctic Sea.

(*a*.) As many as twelve species of Corals are known to inhabit these inhospitable waters, illustrating the fact that the temperature of the Arctic waters is no barrier to the well-being of a very large number of Invertebrata (especially Polyzoa and Foraminifera), or even of a group of them which reaches its highest development in tropical seas. These twelve species comprise exclusively Alcyonaria, viz.: seven *Alcyoniidæ* (*Alcyonium*, *Ammothea*, *Rhizoxenia*, *Eunephthya*, *Gersemia*); two *Primnoidæ* (*Primnoa*, *Lithoprimnoa*); two *Isididæ* (*Isidella*); one of the *Briareaceæ* (*Briareum*). A stony coral has been recorded, but its occurrence cannot be accepted as genuine.

(*b*.) In the North Temperate regions of the Atlantic, as elsewhere, an important distinction exists between the deep and shallow-water faunas. In this district the deep fauna is better known than in any other part of the world. Near our own and the American coasts we find seven species of *Alcyonium*, some small genera of the same family, containing one or two species each (*Rhizoxenia*, *Anthopodium*, *Anthomastus*), and a few stray *Gorgoniidæ*. Among Stony Corals (Zoantharia) *Caryophyllia* predominates (but in deep water), and several allied forms appear. *Sphenotrochus* here represents *Flabellum* of the Indo-Pacific region. *Lophohelia prolifera* and *Amphihelia* are attractive branched forms of wide distribution in moderately deep water. The Hydrocorallinæ, the third great division of Corals, are also represented here, by species of *Allopora* and a *Stylaster gemmascens*.

Passing to (*c*) the Subtropical Atlantic, we find (*a*) the West African islands and the neighbouring coasts to exhibit more of the Porous and colonial forms of Stony Corals than in the more northern seas; *Madracis asperula*, *e.g.* extending across to the West Indies. *Dendrophyllia* and *Balanophyllia* appear to be quite at home, judging from the abundance in which they are found. *Caryophyllia* is still largely represented in the deep sea. *Flabellum* here begins to appear, replacing the northern *Sphenotrochus*. *Lophohelia prolifera* extends even beyond here far into the South Atlantic. Among Alcyonaria the Precious Corals

(*Coralliidæ*) here first appear, the Red and a White form being found. *Leptogorgia* is attractive and well represented here.

The Mediterranean fauna (β) has the same general *facies* as the contiguous portions of the Atlantic, but has some species peculiar to it, as *Cladocora cæspitosa* and a number of *Paracyathi* (Duncan), but most of its species extend into the North Atlantic. It has but few *Gorgoniidæ*, several fleshy Alcyonoids, the Red Coral (*Corallium*), numerous simple Madrepores, and the almost ubiquitous compound *Lophohelia prolifera*, but not a single true Reef Coral, except *Astrocœnia pharensis*, a lately discovered member of an otherwise fossil genus, not elsewhere found. These facts should be borne in mind, as in dealing with the Red Sea, separated from the Mediterranean by only about 100 miles of sandy and rocky land, we shall find a reef-coral fauna, perhaps the richest in the world, but no species of any Coral which is found in the Mediterranean.

In (e) the tropical Atlantic, but little is known of the Corals of the Equatorial Coast of West Africa (a) ; but here, as in the north, *Eunicella* is a prominent Gorgoniid. *Leptogorgia* is abundant, as in the Pacific. In mid-ocean (β) *Lophohelia prolifera* and nearer to Brazil *Madracis* are still found at considerable depths, and the widely ranging *Solenosmilia variabilis*, and a species of *Stephanotrochus*, a detached form, cross the ocean here, while *Deltocyathus italicus* (shown by Mr. Moseley to be identical with an Italian fossil) comes south from Massachusetts. *Caryophyllia* extends from the north by its species *C. maculata*, also found in the Pacific. These species, it should be observed, are all of wide range, and inhabit great depths.

The West Indies (γ), however, are the great focus of Corals in the tropical Atlantic. This was to have been expected from the great varieties of depth presented by the bottom, from the high temperature of the water, and the absence over most of the area of considerable accessions of fresh-water from rivers. Of Alcyonaria, we have here a few *Xeniidæ* (*Ammothea* and an endemic genus, *Erythropodium*), a few genera from temperate seas (*Primnoa*, *Briareum*), and several genera (*Eunicea*, *Rüsea*, *Acis* *) of the same family quite peculiar to this area, *Eunicea* alone contributing about twenty species to its fauna. *Plexaura*, though also

* Since recorded from the Indian Ocean.

found in the Pacific, has several species here, and *Pterogorgia* attains a very great development in size. Of Zoantharia, *Paracyathus*, *Rhizotrochus*, *Desmophyllum*, and numerous other genera represent the *Turbinoliidæ*. *Oculinidæ* are well represented by *Axohelia*, *Amphihelia*, and *Oculina*. Of *Astræaceæ*, deep-sea rather than shallow-water forms occur, *e.g.* *Antillia* (the only recent species); *Manicina* and *Lithophyllia* seem also to be confined to this region. *Diploria* and *Mæandrina*, *Siderina* and *Orbicella* are well represented here, though not confined to the Atlantic. The Cladocoracean genus *Astrangia* is found on both sides of the isthmus; the large genus, *Porites*, though chiefly found in the Pacific, is just represented here. Of other *Porosa*, *Balanophyllia* is quite at home here, as in the Atlantic generally; *Madrepora* has several species, but its true home is the Indo-Pacific region.

On the aspect of the West Indian Coral fauna in general, Pourtalès remarks (Catalogue Mus. Comp. Zool. Cambr., Massachusetts, viii., pp. 33-50) that the existing West Indian deep-sea coral fauna agrees much more closely with the corresponding Recent and Tertiary European fauna than with the West Indian fossil fauna. I have already drawn some comparisons between the West Indian and Pacific Coral faunas; it seems of some interest to look at Verrill's comparison of the two sides of the Isthmus of Panama with respect to this subject. It should be noticed that the species enumerated form but a small proportion of those occurring in the tropical regions of the two districts, and represent only those known to Verrill himself at the time of writing (1866).

According to Verrill (Proc. Boston Soc. Nat. Hist. x., p. 323), the following are the main aspects of the two faunas:—

At Aspinwall (West Indian side).	*At Panama* (Pacific side).
1. *Coral Reefs*, with the same features and same species of Corals as Florida and West Indies.	1. *No true Coral Reefs* here as on the West Coast of Central America, a totally different set of families except *Porites panamensis* and *Stephanocora*.
2. Chief Zoantharia, *Porites astræoides*, *clavaria*, *Madrepora palmata*, *cervicornis*, *prolifera*, *Mæandrina clivosa*, *labyrinthica*, *sinuosa*, *Manicina areolata*, *Sidernia radiata*, *galaxea*, *Orbicella cavernosa*, *annularis*, &c.	2. *Stephanocora stellata*, *Astrangia Haimei*, *pulchella*, *concinna*, *dentata*, *costata*, *Phyllangia dispersa*, *Ulangia Bradleyi*.

3. *Gorgoniidæ:* Agree in general with West Indies. *Pterogorgia,* *Xiphigorgia,* *Plexaura,* *Plexaurella* *Eunicea.*	3. None of the West Indian genera appear to occur. *Gorgonia ramulus, aurantiaca, Leptogorgia rigida, Rhipidogorgia Agassizi, media, stenobrachis, Muricea acervata, hispida, echinata, hebes, robusta, appressa, Echinogorgia arbuscula, Sympodium pacificum.*

The Brazilian fauna (δ) has a good deal in common with that of the West Indies. There are a few reefs at some distance from the coast (Abrohlos Is., Bahia, &c.), but the fresh waters of the Amazon and Orinoco appear to have kept them in check. Besides some Alcyonaria already mentioned from the West Indies, we may notice, as found here, two genera peculiar to the district, *Filigella* and *Phyllogorgia*. Of the Zoantharia not much is known, except concerning the deep-water forms, of which we find here a *Bathycyathus*, a *Flabellum*, and a *Sphenotrochus*, which appear not to be found elsewhere. The rare and remarkable *Haplophyllia*, with a tetrameral arrangement of its septa, extends down from the West Indies.

On going further south of the Equator, we find a remarkably rich locality (ε) off the mouth of the Rio de la Plata, in deep water, probably out of the reach of the influence of the fresh water, owing to the inferior density of that element, otherwise it would appear to be an unlikely locality for such essentially marine forms. But it is chiefly *Hydrocorallinæ* here, whose occurrence is remarkable; of these the genera *Sporadopora* and *Spinipora* are peculiar to this spot, and the species *Allopora profunda* and *Stylaster densicaulis*; *Errina labiata* also occurs here and off Tristan Da Cunha. The coast fauna is little known.

In Patagonia we come in contact with the Pacific region. Here *Desmophyllum ingens*, an immense Turbinoliid, of a Mediterranean and West Indian genus, and, identical perhaps, with a Sicilian tertiary fossil, is the most striking Zoantharian; a fine *Flabellum* also occurs here, an *Astrangia*, and a few *Gorgoniidæ*. On the opposite side of the Atlantic, the Cape (ζ) produces several fine *Gorgoniidæ* and *Briareidæ* (*e.g. Lophogorgia palma* and *Solanderia verrucosa*). The coast is not adapted for the growth of shallow-water Stony Corals in any abundance.

B. The next region is the Indo-Pacific, which must be taken as undoubtedly a true faunal region, New Zealand, the Red Sea, and Japan being perhaps separated as sub-regions.

Beginning with (α) the North Temperate part of this area, we find Japan possessing a fauna which, so far as it is known, but slightly resembles that of the North Atlantic. Thus of Alcyonaria we find here a *Primnoa*, and a form allied to *Isis;* also a *Desmophyllum*, a *Balanophyllia*, and quite a number of *Flabella.* But here and off China we miss *Alcyonium* and *Eunicella*, *Caryophyllia* and *Paracyathus*, and have instead *Calyptrophora*, *Mopsella*, *Cyathohelia*, *Eupsammia*. The Sandwich Islands (β), in a slightly more southern latitude, have a true reef-coral fauna, and in the Bonin and Loochoo Islands (γ), between the parallels of 30° to 25° N., we have already the reef Corals *Turbinaria* (probably) and several *Madreporæ*, this genus being unknown in the West African islands of about the same latitude, but probably exclusively tropical in the Atlantic. The Stylasterid *Endohelia japonica* is peculiar to Japan, and off its coast the deep water presents quite a focus of *Pennatulida*. The Pacific *Euphylliaceæ* are already represented in this subtropical region by two *Euphylliæ*. *Flabellum* continues to be largely represented, but the Porous and Astræid Corals now assert their supremacy, a supremacy which they maintain over the other Aporous Corals (*Turbinoliidæ* and *Oculinidæ*, &c.) throughout the whole Indo-Pacific region, except in the South Temperate districts, whose lower temperature keeps out these tropical forms. Thus in the South Chinese seas (δ) *Eupsammia*, *Heteropsammia*, and *Rhodopsammia*, replace the externally very similar *Caryophyllia*, *Turbinolia*, and *Trochocyathus* of the Atlantic, and to the Reef forms already mentioned are added *Lophoseris*, *Porites*, *Montipora*, *Psammocora*, *Stephanoseris*, *Diaseris*, *Plesiastræa*, *Pocillopora* (one of the *Tabulata*), mostly unknown out of the Indo-Pacific region.

These forms are more or less replaced in the tropical parts (ϵ) of the Pacific and Indian Oceans (*e.g.*, Malay Archipelago and Pacific Islands) by *Galaxea*, *Mussa*, *Cœloria*, *Hydnophora*, *Acanthastræa*, *Favia*; and numerous Astræaceæ, as *Prionastræa*, &c., here also attain their maximum, showing that here the Astræidæ attain their highest development. *Herpetolitra*, *Fungia* *Leptoseris*, &c., represent the *Fungiidæ*. The Red Sea (ζ) fauna is, in spite of its higher latitude, perhaps quite as rich in genera and species of these groups, and abounds in the softer Alcyonaria (*Alcyonium*, *Spongodes*, *Ammothea*), and thus presents a striking contrast to the neighbouring Mediterranean waters. Perhaps the most attractive part of the tropical superficial fauna to the

travelling naturalist's eye must be that of the Alcyonaria; here, we have *Anthelia*, *Xenia*, *Sympodium*, *Telesto*, *Sarcophytum*, *Spongodes*, *Siphonogorgia*, species of *Alcyonium*, *Heliopora cærulea*, *Tubipora*, and several *Melithæa*. Most of these are of striking form and colour, and all peculiar to the region, and are said to give these reefs and shores a marvellously beautiful appearance.

On the Australian coast we find a continuation of the Tropical fauna for some distance southwards. New Zealand (η) has a small number (in the present imperfect state of our knowledge of this district) of mostly endemic species, of *Rhipidogorgia*, of *Suberia*, amongst the Alcyonaria; and of *Cœnopsammia*, *Desmophyllum*, *Conocyathus*, and *Cylicia*, amongst the Zöantharia. *Suberia* and *Conocyathus* are peculiar, as genera, to these seas.

Turning to the second heading, *The Causes of Distribution*, I find one important cause to be the *depth of the water*, which presents a barrier to forms which are suited only to certain depths. The distribution of Zoantharia in the Atlantic should be studied in the light of the facts of the bathymetry of this region. Thus we have a long stretch of water of or beyond 3,000 fathoms in depth, extending from about 36° N. lat. and 50° W. long. southwards nearly to Trinidad, although not very broad; a band of similar depth lies off the Guinea coast, and extends for about 12° north and south, while midway between Brazil and South Africa a long belt of this deep water reaches from the Equator to about 32° S. lat. At these points, then, the passage across the ocean is barred to all Corals, except possibly a few of the more bathymetrically ubiquitous, as *Bathyactis*; and if any ordinary deep-sea form is to effect a crossing from one side to the other, it must be by way of some of the passages of shallower water which intervene between these abyssal tracts. But even outside this deep area, between the United States and West Indian seas and our own is interposed a broad band of water of 2,000 fathoms and upwards in depth; hence probably the extremely few and doubtful cases of specific identity of forms found on the two sides of the North Atlantic.

Another cause of distribution is *temperature*. The Isothermal line of 68° Fahr. in the surface waters, in the winter, constitutes the limit to the thermal conditions under which reef-corals can live. This line passes in the North Atlantic from about the Canary Islands on the east across to Carolina, in the United States, on the west. The Bermudas are

close to this line, which leaves the true West Indian Islands well within the area of beneficial warmth. In the South Atlantic it passes from near the south of Brazil rapidly northwards to within about 10° of the Equator. A few coral reefs occur off the Brazilian coast; those of the West Indies are too well known to need mention. Neither North or South Africa boast of any reefs worthy of the name, although, as we see, the temperature admits of it over a large extent of the coast. In the North Pacific the line runs from near the apex of the peninsula of Lower California to the islands off the south of Japan, passing just to the north of the Sandwich Islands and Hawaii. In no part of the world is the intimate relation of temperature to coral life better illustrated than here, for at all the four points mentioned reef-corals are well developed, though not found further north.

In the South Pacific the line begins just south of the Galapagos Islands, off Peru, bends southwards, and passes along the Tropic of Capricorn, to the south of the Society and all the Polynesian Islands, and, leaving New Zealand a little to the south, reaches the Australian coast at about the latitude of Port Jackson. The Polynesian Islands are distinguished for their coral reefs; New Zealand has none. The vast barrier reef of the East Australian coast ceases just north of the point where the isotherm of 68° reaches the coast. In the Indian Ocean the line runs approximately parallel to the Tropic of Capricorn, well to the south of the numerous coral-island groups which stud the seas to the north and north-west of Madagascar and to the south of India.

The possible influence of *geological conditions* has been touched on while discussing the relations of the West Indian fauna. Although the shallow-water faunas of the West Indies and the Pacific are very different as regards species, yet there is so much agreement between them in genera as to lead to the belief that at no very distant period a communication existed between the two seas, probably in one of the earlier tertiary periods. Other causes have probably co-operated in producing the present distribution; the above appear to be the chief ones.

After the reading of this paper some remarks were made by the President on the geological features of the district which the Association were about to visit on the following Whit-Monday and Tuesday.

EXCURSION TO REDHILL AND CRAWLEY (NORTHERN VALLEY OF THE WEALD).*

SATURDAY, MAY 6TH, 1882.

Director:—J. LOGAN LOBLEY, Esq., F.G.S., &c.

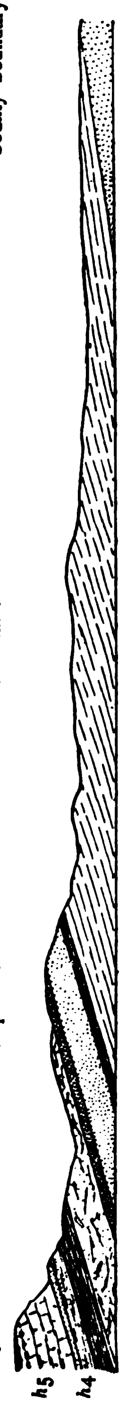
(*Report by* THE DIRECTOR.)

On arriving at Redhill Junction Station the party at once made their way to Redhill Common, on the summit of a hill that rises boldly on the south of the town to an elevation of 475 feet above sea level, and affords a complete view of the district to be observed. The central elevated region (the Forest District), extending east and west, rises from a valley, or rather low plain, lying along its northern side, while a similar vale skirts it on the south, both these vales being overlooked on the north and south respectively by elevations which form the bounding escarpments of the Wealden Area. The central elevated district consists of the Hastings Sands, the parallel vales to the north and south of the Weald Clay, and the bounding escarpment of the entire area of the Lower Greensand and the Chalk, the latter formation forming the North and South Downs. Although the ranges of the Chalk Downs are of about equal general elevation, the Lower Greensand on the south forms features insignificant compared to those of that formation on the north, which become in many places bold hills, and in one case, that of Leith Hill, surpass even the Downs in altitude.

Redhill Common is on the Lower Greensand escarpment, and from its commanding elevation, looking northwards, the parallel Chalk escarpment of the North Downs is well seen for a long distance running east and west, the nearest point being about a mile and a half distant across the beautiful intermediate Cretaceous

* This excursion was the first of a series of three intended to be a sequel to the Weald series of 1879, which enabled Members of the Association to make themselves acquainted with the geology and physiography of the country between the edge of the London Tertiary Basin at Orpington and the summit of the Weald at Crowborough Beacon. The present series was arranged to give Members an opportunity of surveying the Weald across the entire breadth along the line of section between London and Brighton from the North Downs to the South Downs. The first of the series was from Redhill to Three Bridges (Northern Valley), the second from Three Bridges to Haywards Heath (Central Elevation), and the third from Haywards Heath to Ditchling Beacon (Southern Valley).

SECTION OF NORTHERN VALLEY OF THE WEALD. (*Length of Section, about 9 miles.*)



N.B.—Vertical Scale great exaggerated.

EXPLANATION OF SIGNS.—h1''' Tunbridge Wells Sand. h1 Weald Clay, h2 Lower Greensand, h2' Atherfield Clay, h2'' Hythe Beds, h2''' Sandgate Beds, h2'''' Folkestone Beds, h3 Gault, h4 Upper Greensand, h5 Chalk.

valley. Here the Lower Greensand escarpment is cut across by a deep valley, through which the London and Brighton high-road and railway run. This gorge is in a line with a fault crossing the longitudinal valley, and extending to the Chalk escarpment at the Merstham tunnel.

Turning to the south, the view from Redhill Common extends over the whole Weald Clay vale to the central elevations. On this occasion, indeed, the atmosphere being exceptionally clear, the South Downs and Chantlebury Ring were distinctly seen, and thus the entire breadth of the Wealden Area from the North to the South Downs was before the eyes of the delighted geologists. The highest part of the Common consists of the Folkestone Beds of the Lower Greensand, which have the usual dip to the north, and pass under the Gault in the valley, but on the face of the escarpment the underlying Sandgate Beds, the Hythe Beds, and lower still, the Atherfield Clay, occur in regular sequence. A very fine exposure of the Folkestone Beds is seen in the large sand-pits on the eastern side of the hill, where these beds consist of brightly coloured sands, chiefly of a beautiful deep pink, ranging to crimson. At about half a mile to the east, and at the base of the escarpment, the party visited a section of Atherfield Clay, worked here for bricks in conjunction with Weald Clay from the adjacent Earlswood Common, the commencement of the northern Weald plain.

This common was now traversed, the wet and boggy ground bearing witness of the changed character of the underlying strata. It was pointed out that the slight ridges noticeable on this Common were due to thin bands of limestone, which occur in the Weald Clay. The limestone, where seen, is partly decomposed, but gives evidence of its fresh water origin by yielding *Paludinæ*. Mr. Topley ("Geology of the Weald," p. 102) gives the following particulars of the subordinate beds of limestone and sand found at different horizons in the Weald Clay, the maximum thickness of which near Leith Hill is estimated at from 900 to 1,000 feet :—

7 Sand.
6 Limestone, "Sussex Marble" (large *Paludina*).
5 Sand and Sandstone, with Calcareous Grit.
4 Limestone (large *Paludina*).
3 Limestone (small *Paludina*).
2 Sand and Sandstone.
1 Horsham Stone.

Of these, the lowest, the Horsham Stone, is the most important.

The old coach road to Brighton was now gained, and followed for the remainder of the journey to Crawley. Another of the limestone-based ridges is crossed south of Earlswood and Petridge Common, and still another at Horley Lodge, the latter forming the water-shed between two branches of the Mole. After these elevations are passed the Weald Clay forms a perfect plain. This flat country, destitute of sections, though well wooded and cultivated, and smiling with the beauty of early May, was not calculated to inspire geologists with very great interest, and the miles became somewhat wearisome, but nevertheless nearly the whole party continued the walk through Horley to the little old roadside town of Crawley, passing over, on the way, the county boundary between Surrey and Sussex. After the evening repast, some of the party took train for London at Crawley Station, and the remainder completed the prescribed route by walking to Three Bridges Station.

EXCURSION TO TILGATE FOREST, CUCKFIELD, AND HAYWARDS HEATH.*

(CENTRAL ELEVATIONS OF THE WEALD.)

SATURDAY, MAY 20TH, 1882.

Director:—J. LOGAN LOBLEY, Esq., F.G.S., &c.

(*Report by* THE DIRECTOR.)

Three Bridges Station, at which the Members assembled, is a well-situated point of departure from which to cross the central elevations of the Weald on the line of section between London and Brighton, the line of junction of the Weald Clay and the Hastings Sands crossing the railway at this place. A detour of half a mile to the west over the Clay lands enabled the party to avail themselves of the forest road which the Lord of the Manor had courteously made free to the Association. Immediately the Weald Clay is left behind, dense woods are entered, and these, with the rising sandy ground, leave no room for doubt that the Forest District has been reached. The coincidence of the boundary between the Weald Clay and the Hastings Sands with that between the cultivated flat fields and the wooded rising ground is very remarkable, and affords a fine example of a complete subordination of the physiography and productions of a country to its geology.

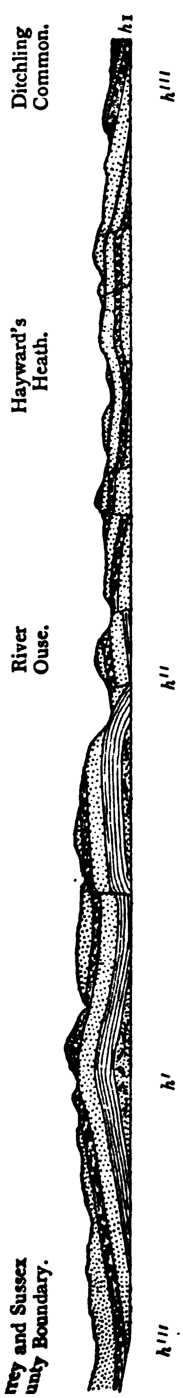
A walk of a mile brought the party to a quarry by the side of the railway, affording a good exposure of the uppermost beds of the Hastings Sands, the subdivisions of which were described. They are briefly as follows :—

Subdivisions.	
Upper Tunbridge Wells Sands (with Tilgate Grit), in two parts separated by Cuckfield Clay (local, 15 feet)	100 to 200 feet
Grinstead Clay	10 to 80 feet
Lower Tunbridge Wells Sands	50 to 100 feet
Wadhurst Clay (with Clay Ironstone)	120 to 150 feet
Ashdown Sands	150 to 500 feet
Fairlight Clays (local, 360 feet)	

The Upper Tunbridge Wells Sands, as seen in the Tilgate

* Second of the Weald series.

SECTION OF THE CENTRAL ELEVATIONS OF THE WEALD. (*Length of Section, about 12 miles.*)



N.B.—Vertical Scale greatly exaggerated.

Explanation of Signs.—*h'* Ashdown Sands, *h''* Wadhurst Clay, *h'''* Tunbridge Wells Sands, *h1* Weald Clay.

district, are very variable, containing in some places, as at this quarry, beds of good, though not very hard, building stone, bands of clays, and pockets of hard nodular calcareous blocks with ferruginous coatings. At other places they are simply compacted sands, sometimes beautifully white glass-sands, with thin shelly sandstones, and at others, as at Cuckfield, they contain the hard calcareo-siliceous stone known as "Tilgate Grit" with argillaceous beds, "Cuckfield Clay."

Leaving this quarry, higher ground was traversed, and a picturesque route through the forest led to "Cinder Banks," at which point the path descends and crosses the railway to a secluded hollow, in which one of the head waters of the Mole meander over Grinstead Clay. The Grinstead Clay separates the Upper from the Lower Tunbridge Wells Sands, and has a maximum thickness of about fifty feet in the neighbourhood of East Grinstead. This Clay has a general resemblance to the Wadhurst Clay below the Lower Tunbridge Wells Sands, but does not appear to contain so much ironstone. As the land rises rapidly, the Lower Tunbridge Wells Sands are not seen, and the "Clay" occupies but a very narrow area where the stream has cut through the "Sands."

Hence the party made their way by ascending paths through an extensive area covered with small beeches, very beautiful at this time of the year, but completely shutting out all

landmarks. This in the case of so large a party was the cause of some anxiety, but by keeping well together the summit of Balcombe Down, 471 feet above sea level, was at length successfully reached, and a commanding position on the great spoil heap over Balcombe tunnel (the summit of the London and Brighton railway) was taken up. The Director here explained that the principal anticlinal axis of the Weald had now been reached, the same axis as that visited by the Association in July, 1879 (see "Proceedings of the Geologists' Association," Vol. vi.). Mr. Topley has clearly shown by the interesting map at the end of the "Geology of the Weald" that there are several anticlinals in the Wealden Area having a general parallelism, but that one passing through Crowborough Beacon, Ashdown Forest, Balcombe Down, St. Leonards Forest, and so on to Horsham appears to be the chief passing, as it does, through the central highlands, and being coincident at a little east of Balcombe Down with the water-parting of three hydrographical areas, those of the Medway, the Mole, and the Ouse. An extensive and varied view over a large portion of the Forest District of the Weald rewarded the geologists, who lingered some time to enjoy the magnificent and physiographically most interesting prospect.

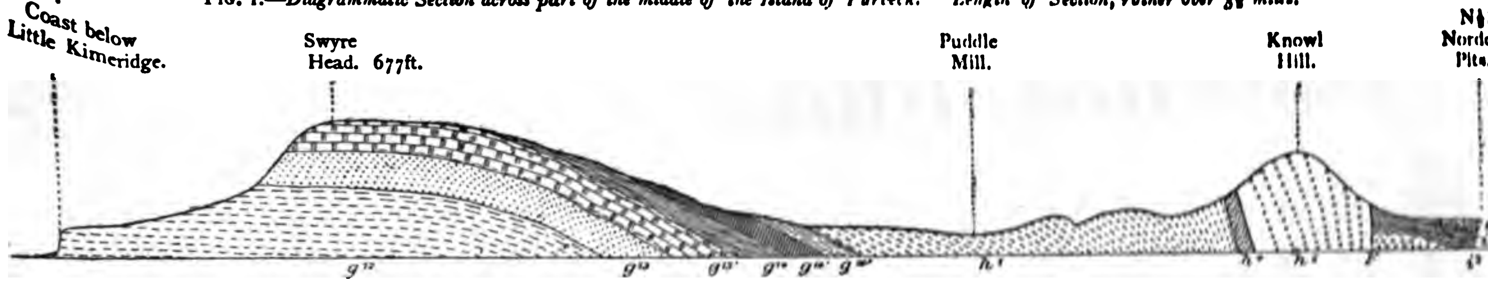
All now proceeded westwards along the anticlinal by a high level road coincident with the water-shed of the Ouse and the Mole. At Handcross the London and Brighton high-road was struck, and after the party had obtained some much-needed rest and refreshment, was followed. The road, running southwards, descends by Staplefield Green to the Ouse Valley, at the bottom of which, and rising on the south side to some elevation, occurs a remarkable inlier of Weald Clay running east and west for about six miles. This is caused by the folding of the strata, which dip from the anticlinal at Handcross, and present the Weald Clay along a synclinal at a lower level than the Tunbridge Wells Sands, which are, however, lifted up again on the south by a fault.

The strata to the south are much faulted, and the Tunbridge Wells Sands, the Grinstead Clay, and patches of Weald Clay form the ground in a most irregular manner. Near the summit of the south side of the valley the Tunbridge Wells Sands afford a fine white glass-sand without any cementing material, though at a few yards distance a shelly sandstone is visible.

Some distance further, at a higher level, at Whiteman's Green,

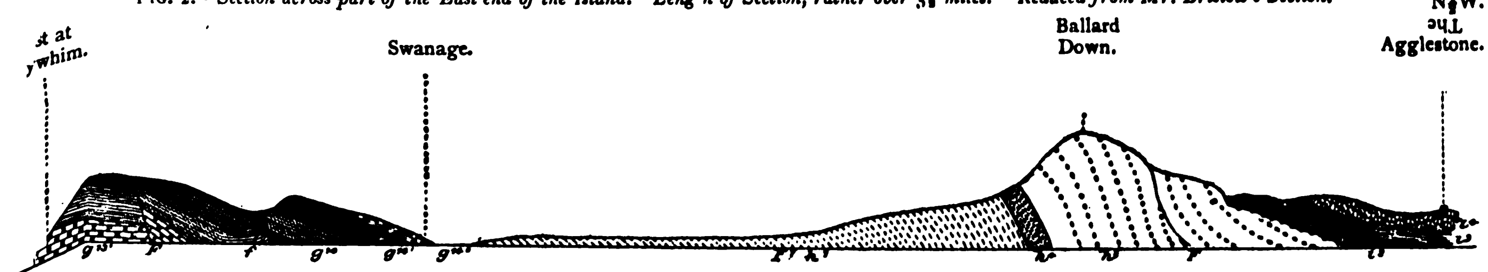
near Cuckfield, the famous "Iguanodon Quarry" of Mantell is reached, where the Tilgate Grit, with a conglomerate, is covered with a patch of Weald Clay. The Iguanodon tooth, discovered here in 1822 by Mrs. Mantell led to the determination of this animal, whose bones had some years previously been observed by William Smith. It was thus found to have been a herbivorous reptile analogous to the Iguana of South America, and doubtless it luxuriated in the woods which clothed the banks of the great Wealden river. Fragments of bones of this reptile are frequently found in the quarry, and a little store collected by the quarrymen was quickly dispersed amongst the visitors. The much-sought-for tooth, however, was not seen. The town of Cuckfield was then passed through, and at the invitation of Major Sergison, a visit was paid to Cuckfield Place, a fine specimen of an old English residence, the foundation of which dates back to the time of King John, though the present house is of the Tudor period. After a very hospitable entertainment, antique wood carvings, an unique collection of Figian and Japanese objects, and (of especial interest to geologists), fine castings of Wealden iron, occupied attention for some time, and the party then assembled in the park overlooking the Southern Weald Vale, commanding a fine view of the range of the South Downs, with Ditchling Beacon, the Devil's Dyke, and Chantlebury Ring. Returning to Cuckfield, the Members dined at the King's Head Hotel, the chair being occupied by the President, who expressed the thanks of the party to the Director. Time being limited, little delay ensued, and a further walk to Haywards Heath Station over very remarkable ripple-marked Wealden flagstones terminated the day's proceedings.

FIG. 1.—*Diagrammatic Section across part of the middle of the Island of Purbeck. Length of Section, rather over 3½ miles.*



The line of this section is about a mile west of the meridian of Corfe Castle, and strikes the coast half-way between Kimeridge Bay (west) and Chapman's Pool (east). The Upper Kimeridge alone is exposed, dipping eastwards away from the anticlinal of Kimeridge Bay, which is transverse to the main axis of curvature. The beds on the Purbeck slope are more irregular than is shown in section. The thickness both of Purbecks and Wealden rapidly diminish towards the west, and this rule applies to all the beds below the Chalk.

FIG. 2.—*Section across part of the East end of the Island. Length of Section, rather over 3½ miles. Reduced from Mr. Bristow's Section.*



This section is drawn a little inland of the actual coast, but so as to express its chief geological features. The fault in the Wealden (h^1) scarcely reaches the coast. The upper part of h^1 contains the "marine band," the "Punfield Beds," and the uppermost "Lower Greensand." At the base of h^4 are dark clays, which represent part of the Gault. The fault which, at Knowl Hill, separates the Chalk from the Tertiaries, here passes through the Chalk itself. The junction of Chalk with Tertiaries is marked by a series of funnel-shaped pits, or "pot holes."

EXPLANATION OF SIGNS.

g^{12} Kimeridge Clay, g^{13} Portland Sand, $g^{13'}$ Portland Stone, g^{14} Lower Purbecks, $g^{14'}$ Middle Purbecks, $g^{14''}$ Upper Purbecks. ... Chalk, i^2 Woolwich and Reading Beds, i^3 London Clay, i^4 Lower Bagshots.

EXCURSION TO THE ISLE OF PURBECK.

Whit Monday, May 29th, and Following Day.

Directors—The President and Prof. Morris, M.A., F.G.S.

(*Report by* The President.)*

First Day.—Owing to the distance from London, many of the members had arrived at Wareham, Swanage, and other places towards the end of the previous week, but these were largely re-inforced by the party leaving Waterloo at 8.5 a.m. Wareham, 115 miles from London by road, was reached between twelve and one o'clock.

Wareham occupies a position of some importance between two rivers which unite immediately below the town, in the very centre of that inlet of the Hampshire basin known as the Trough of Poole. This Trough consists of a synclinal of Tertiary beds lying in the fold between the Purbeck axis on the south and the Dorset downs on the north. These downs occupy a block of wild and elevated chalk country about 19 miles in length between the gorge of the Frome at Maiden Newton, and the gorge of the Stour at Blandford. They culminate in Rawlsbury, or Bullbarrow (Badbury Rings), said to be 927 feet above sea level—a salient of the escarpment overlooking the Vale of Blackmore. The Trough, is closed on the west, as regards the Tertiary Beds, by the curving round of the chalk in the neighbourhood of Dorchester, so that, beyond this point, the chalk area is very wide.

The Isle of Purbeck faces these northern downs. Strictly it should be described as a peninsula twelve miles in length from Worbarrow Bay on the west to Swanage Bay on the east, with a maximum width of about seven miles on the meridian of St. Alban's Head. The neck of the peninsula is crossed by a line drawn from the head of Worbarrow Bay, almost due north to the Frome at Stoke. The northern half of this peninsula is a dreary waste of Middle Tertiaries penetrated by innumerable creeks in connection with the tidal estuary of the Frome. The southern half is composed of Secondary Rocks inclined for the most part at a high angle, and may be said to contain nearly all that is of interest in the "Island." It is ruled off on the north by the

* The substance of the remarks made at the previous meeting is to some extent incorporated with this report.

highly tilted chalk ridge, and on the south presents its headlands, cliffs, and bays (formed entirely of jurassic rocks) to the unquiet waters of the English Channel.

The distance from Wareham station to Corfe Castle is 4½ miles, and, as the latter town is approached, the unique situation of the Castle is more fully realized; but before entering the gorge the party stayed to inspect the workings in the Tertiary Beds on the left-hand side of the road. For miles towards the foot of the chalk ridge the refuse heaps of these excavations for pipe-clay seam the brown heath with a line of mounds, which, at a distance, might almost be taken for moraines. These beds belong to the Lower Bagshots, and are largely associated with the leaves of dicotyledonous plants. Mr. Brodie has also noted insect remains from this horizon.

The Matcham clay works, visited on this occasion, are on the opposite side of the road to the Nordon pits (indicated in the diagram), and present some unexpected features. In the first place the beds are dipping nearly due S. at an angle of 15°, being exactly the reverse of what the average inclination of the beds must be in this region, *i.e.*, they dip towards the longitudinal fault at the base of Knowl Hill.

SECTION OF THE MATCHAM WORKINGS.

Black Earth, and surface material, with flints—indications of sepulture, &c.	
1. Loose white sand with *Ironstone Bands* at base ...	20-40ft.
2. Stiff yellowish or variegated clay—"pipe-clay" ...	30ft.
3. Pure "Potters' Clay," with leaves, &c.	8ft.
4. Lignite, or Brown Coal	2ft.
Clay	

The loose sand is very full of water and exceedingly troublesome. The ironstone grits are very similar to those used for mending the roads hereabouts.

No. 2, the yellow or variegated clay, is taken off in large oblong spits, and left in the workings. No. 3 is the article so much sought after; it is a soft, white, and somewhat unctuous clay and is no doubt pretty nearly pure kaolin. In the Nordon workings the lignite (No. 4) was sometimes found to be 7 or 8 feet thick, and was occasionally used as fuel by the workpeople.

From this place to Corfe Castle is only a few hundred yards. The great east and west fault once crossed, the indurated chalk is

immediately seen dipping north about 70°. *Belemnitella* was noted in the highest beds, which are quarried for road stone. There are but few flints in these highest beds.

The two streams which have excavated the double gap in the Chalk ridge unite just below this quarry at about 50 feet above sea level. The high road follows the most easterly of these gorges, having the curious insulated monticle on which the Castle stands high upon the right. At a suitable place the members dismounted from the carriages and proceeded at once to swarm up the steep acclivity beneath the eastern ramparts of the now dismantled fortress, where they were joined by the directors and the rest of the party. The day was fine and warm, and there was every opportunity of observing the physical features for which this curious spot is so remarkable. Towards the north extended the Tertiary plain just traversed, bounded in the far distance by the Dorset downs. On either flank were seen the deep gorges which separate the monticle from the rest of the Chalk ridge—Knowl Hill on the west, Challow Hill on the east. The area thus insulated may be about 20 acres in extent, measured at its base, sloping gently southwards—that is towards the town of Corfe Castle. So narrow is the outcrop of the Chalk here, owing to the high angle of dip that already at the drawbridge the Upper Greensand is reached; the monticle itself therefore must consist of the Lower and Middle Chalk. There are no signs of any transverse disturbance, or material change of strike; hence it is probable that the peculiarity of a double gap is simply due to the fact that the drainage of the longitudinal Wealden Valley behind is effected by two streams which unite just outside the chalk ridge. In all other respects the double gorge at Corfe may be regarded as analogous to those in connection with the Wealden of the south-eastern counties.

If archæologists are right, the phenomenon of the excavation was recognised by the Anglo-Saxons in the name—originally Corvesgate, from the Anglo-Saxon *Ceorfan*, to cut; and truly it is one of nature's most impressive cuttings, though small compared with some which might be mentioned. From early times this spot, which was in a certain sense the key to the Isle of Purbeck, had been the favourite resort of the Saxon princes. In spite of what the guide books say, no one believes that the Castle, whose ruins we now see, was built by Edgar; but there is no reason to doubt the old chronicler, who tells us that the murder of Edward

the Martyr took place (A.D. 978) at the *Hospitium* of Elfrida, "ubi nunc castrumi satis celebre constructum est." Thus, when self-appointed guides would show us the gateway where the unsuspecting Edward accepted the treacherous hospitality of his stepmother, we may receive the information in a non-realistic sense, and as indicating at least the spot where the gateway ought to have been at the time of the murder.

A portion of the masonry of the inner face of the S.W. wall may have been erected before the Norman Conquest according to Mr. Bond. The actual date of the present *structure* is not perhaps known (said to be Edwardian), but the place figures in English history during the reign of King John. It continued to be a royal fortress till the time of Elizabeth, who made it over to the Hattons, by whom it was sold in 1635 to the Bankes family, with whom it has remained ever since. Its successful defence by Lady Bankes during the Parliamentary wars, and subsequent capture and destruction, are matters of history.

After a brief interval for refreshment, the party reassembled at the Museum, where the Rev. Owen L. Mansel, of Church Knowle, gave an interesting demonstration on the fossils and on the physical history of the district. The Museum was largely stocked by the late Mr. Brodie, of Swanage. It contains capital specimens of Purbeck fossils, including some insect remains, such as the wing of a dragon-fly, a few selected slabs with *Corbula*, *Cyrena*, *Unio*, *Melania*, &c., and many Turtle remains, including specimens of *Pleurosternon ovatum*, *Pl. concinnum*, described and figured by Prof. Owen; also ganoid fish and spines—*Asteracanthus*, *Hybodus*, &c.

There are likewise some interesting fossils from the Punfield Beds and Lower Greensand, including several specimens of *Vicarya*, also *Ammonites Deshayesii*. Especially noteworthy is a species of lobster, said to come from below the "marine band" of Punfield Cove, and thus, according to Mr. Meÿer, showing the connection between these beds and the lobster beds of Atherfield.

Mr. Mansel particularly indicated specimens of marine shells obtained in a tufaceous deposit at no great distance from the town.

The route, after leaving the town of Corfe Castle, crosses the longitudinal hollow represented by the Wealden Beds, and thence ascends the steep slope of the Purbeck Beds to Kingston, which is situated on the Jurassic ridge forming the southern rampart of the Isle.

[redacted]

The new church, dedicated to St. James, is a remarkable building for so remote a village. It has been constructed at a great cost by the Eldon family from stone and marble procured on the estate. The marble for the pillars has been quarried from the *Paludina*-beds of the Upper Purbecks at a place called Blashenwell (?). The stone for the outside has been obtained from the Burr beds of the same locality, out of quarries where there is a reversed or southerly dip. The Burr is a comminuted shell-limestone occurring at the base of the Upper Purbecks. The squared stone used in Corfe Castle is derived from the same beds. The interior mouldings of the church are made of Portland stone from a quarry about half-way between the village and Swyre Head.

This quarry, known as London Doors, was the next point inspected. It shows a very good junction between the Portland Beds and the Purbeck Beds, though somewhat different to any other junction. Being on the summit of the plateau, and situated on the line where the northerly roll is becoming very pronounced, there is much curvature and infiltration. The irregularity of the junction, mainly produced by these two causes, could only be shown by a drawing. Moreover, the uppermost Portland Bed weathers in such a way as to produce the most misleading appearances.

As it was evident from the lateness of the hour that there would be no chance of reaching St. Alban's Head, the Director made a few observations with reference to the Portland beds of the Isle of Purbeck. There are no *Cerithium* and *Cyrena*-beds, such as the two well-marked series observed last year in the Vale of Wardour. In the Purbeck-Portlands all the beds belong to the purely marine type, and are of great thickness. The Portland Stone is divisible into four principal groups, only two of which are well seen in this quarry.

GENERALIZED VERTICAL SECTION OF THE PURBECK-PORTLANDS.

	APPROXIMATE THICKNESS.
1. The topmost bed is a pure fine-grained limestone usually quarried for lime burning. It is sometimes compact or creamy ; sometimes it weathers like chalk. The natives call this bed the "Shrimp," from the quantity of the remains of a small Crustacean. Parts of this are very fossiliferous, but there is usually no definite shell bed	9—10ft.

	APPROXIMATE THICKNESS.
2. A huge Oyster Bed with many species of Monomyaria, especially *Perna Bouchardi*. It has an irregular development. Is poorly shown in this quarry, but largely developed at Tillywhim, where the Oyster Bed forms the top of the Portlands......	4—8ft.
3. The Oolitic Series. At the Winspit quarries this contains two good tiers of freestone, each 7 feet thick. It is most likely the uppermost of these tiers which is represented at London Doors quarry. Banks of *Trigonia gibbosa*, &c.	30—40ft.
4. The Cherty Series, splendidly shown at St. Alban's Head	80ft.

Resuming the route along the plateau towards Swyre Head, the great cirque known as the Golden Bowl suddenly discovers itself on the left. This is a good specimen of those terminal amphitheatres or horse shoes, which show to more advantage in the Jurassic rocks than in any others. Skirting the edge of this cirque at an elevation of over 600 feet, with Encombe House and grounds deep in the hollow below, the party at length arrived on the level summit of Swyre Head, which is the highest point of the Portlandian escarpment—677 feet—and the citadel of the Isle of Purbeck.

Swyre Head.—The afternoon was fine and fairly calm, but the light was unfavourable for obtaining a good panoramic view, especially towards the west. The outlines were traceable, but they were somewhat indistinct. White Nore bears W. by N. 10 miles, Portland W.S.W. 16 miles, the Needles E.N.E. 22 miles. All these were visible. Aided by the map and diagrammatic section, some topographical indications, just flavoured with geology, sufficed to bring home to the members of the party the general features of the scene. The Head itself forms the southern termination of a promontory which projects from the Portlandian plateau, having on the east the deep bowl of Encombe, and on the west the wider and nobler sweep of rock and grassy slope, at the bottom of which the little bay of Kimeridge reposes. This beautiful amphitheatre, facing the south, and cut off, as it were, from all the rest of the world, is remarkable for its fertility, due no doubt to the rich soil produced by the highly phosphatic Kimeridge Clay of this district mixing with the sand and lime of the overlying formations. An anticlinal, transverse to the main

axis of flexure, traverses this hollow, and brings up more than 100 feet of the Lower Kimeridge in the Bay itself. It is not unlikely that something of the nature of a quaquaversal exists thereabouts, since from the hollow of Kimeridge Bay the beds dip west towards White Nore, north towards the Trough of Poole, and east, through Swyre Head, West Hill (terminating in Encombe Point), and Emmit Hill (terminating in St. Alban's Head), all the way to Durlston Head, six and a half miles E. by S. of Swyre Head, where the beds, which are here nearly seven hundred feet above the level of the sea, plunge beneath it. The south-eastern corner of the Isle of Purbeck, including St. Alban's Head, is scarcely affected, therefore, by the chief or east and west axis of disturbance, its dips being in the main easterly. Thus a line drawn from St. Alban's Head to the centre of Weymouth Bay would pretty nearly follow the axis of the Weymouth-Purbeck anticlinal, where the beds in the immediate vicinity of the axial line are but little affected by it. As this line is for the most part about two miles out to sea, the southern wing of the anticlinal is lost until we reach Weymouth Bay itself.

The curiously indented and highly tilted coast facing this axis is so much foreshortened, as seen from Swyre Head, that the effects of the very remarkable scenery of Worbarrow Bay, Mewps Bay, Lulworth Cove, &c.—all outside the Isle of Purbeck—are not fully realized from this point. Perhaps the most striking feature in the landscape is the abrupt ridge of Chalk which is stretched like a cord across the centre of the island, and which may be traced from White Nore through Bindon Hill to Flowersbarrow, where the Isle of Purbeck commences. Next succeeds that portion of the ridge known as Purbeck Hill, lying N.W. of Swyre Head. Almost due north is Creech Barrow, quite 600 feet high, just outside the line of the chalk ridge. This rather singular hill is formed of Tertiary Beds, chiefly the Lower Tertiaries with a small capping of Bagshots, held up in a fork of the great longitudinal fault running on the north side of the chalk ridge. From this point the chalk ridge becomes lower in Knowl Hill, and continues to fall all the way towards the double gap at Corfe, from whence it rises slowly through Challow Hill to Ninebarrow Down, where Cordington attains 654 feet—the highest point of the whole ridge.

One of the most interesting features to note is the steady lowering of the chalk ridge towards the double gap at Corfe, and

then the sudden declivity of the double gap with the castle-crowned monticle in the centre. At the same time one cannot help noticing that the ridge has been pierced where it seems to form the head of a slight curve. This gradual falling away of the chalk ridge towards the breach seems to point to long-continued erosion of some sort previous to the final excavation of the double gorge by the two streams which drain the central hollow. Doubtless the drainage area and consequent accumulation of water was greater formerly. The real dividing ridge of the island—the water parting—is the Jurassic plateau. All the waters falling on the north side of this parting, except such as flow into Swanage and Worbarrow Bays, must pass out at Corfe. Now the area draining into Worbarrow Bay is exceedingly small, and the basin of the Puddle Brook large in proportion; and it thus happens that this stream has done its work of excavating the western gap at Corfe much more effectually than the Byle Brook has in excavating the eastern gap. A reference to the map will show at once that the catchment basin of the Byle Brook is seriously interfered with by a low transverse (N. and S.) watershed, which directs much of the rainfall into the stream entering the sea at Swanage. When the land was more extensive, a different state of affairs must have prevailed, and, as regards the deep hollows on the south side of the water parting, these seem to have formed the heads of valleys passing through a district which has been largely eaten up by the sea, and is even now undergoing a rapid loss.

It became necessary to give up the notion of visiting the workings for "coal" on the cliff near Little Kimeridge, but the view towards St. Alban's Head and Emmits Hill was so inviting that a large portion of the members agreed to accompany the President in order to obtain a nearer peep at the Kimeridge Clay and Portland Sand of those localities. The Upper Kimeridge of these parts is reckoned to be nearly 700 feet thick, and is characterized by paper shales, bituminous shales, and cement stone beds of various qualities. These cement stone beds in their continuation out to sea form the Kimeridge ledges. The coal beds now worked are in the lower part of the Upper Kimeridge, and consist of a block bituminous coal, two feet thick, and above this, of a mass of bituminous shales, ten or twelve feet thick, but variable as to quality. Some of this coal contains a large amount of gas.

One analysis gives 61 per cent. of volatile matter with a balance of 13 per cent. carbon and 26 per cent. ash. The gas has a high illuminating power, but smells horribly. It is generally supposed that the hydrocarbons have been distilled from the putrefaction of animal matter. The material occasionally has a market for the production of asphalt and other compounds. These Upper Kimeridge Beds have a somewhat local development, and have, on the whole, a different fauna from the Lower Kimeridge as exposed in Ringstead Bay. Palæontologically they are characterized by the absence of *Exogyra virgula*, *Ostrea deltoidea*, and *Rhynch. inconstans*, and by the prevalence of *Lucina minuscula*, *Discina latissima*, and *Lucina lineata*. *Am. biplex* is very abundant.

A somewhat scrambling walk brought the party, after rounding the picturesque headland which terminates in Encombe Point, to the Kimeridge Clay of Chapman's Pool, a very noted locality for Upper Kimeridge fossils.* There was but little time for close search, and the beds were very foul, but a few of the more characteristic forms were noted, and one or two tolerable specimens secured. Above the blue shaly clays of this place the bare slopes of Portland Sand are seen to be surmounted by the cherty calcgrits which form the base of the Portland Stone capping the precipices of Emmit Hill, &c. This Portland Sand is a strange mixture of clay, sandy clay, and hard bands, so that few authors agree as to the thickness to be assigned to it. Fitton says 120 feet, Mr. Blake 240 feet. The meaning of this is that there is no good line of demarcation between this formation and the Kimeridge Clay. The thickness of the Upper Jurassics in the Isle of Purbeck is very great, being however pretty much the same as was found to obtain in the Subwealden boring, which must be regarded as being situated in that same fold of the old sea bed which received such immense accumulations during the close of the Jurassic period.

The party now made the best of their way through the picturesque hollow of Renscombe to the farm house at Weston, where carriages were ready to convey them to Worth. Here the last stragglers joined, and a rapid drive through Langton, and past innumerable workings for the Purbeck Stone, which is sought beneath the surface, brought the party to Swanage.

* Cf. Blake, "Q. J. G. S.," Vol. xxxi., p. 198; and Brodie, "Proc. Geol. Assoc.," Vol. iv., p. 517.

Second Day.—It became evident that in order to do justice to the Purbecks of Durlston Bay, the visit to Tillywhim must be abandoned. The members assembled accordingly at the foot of the zigzag path in the very centre of Durlston Bay, at the spot where the fault marked *f* in the section Fig. 2 strikes the coast. This is a good point for commencing. The effect of the throw is very conspicuous. As one faces the cliff, the hard Cinder Bed on the left, which is about the centre of the Middle Purbecks, is brought into juxtaposition with the soft lower beds of the Lower Purbecks on the right. The effect is not exactly the same as is shown in the section, since all the beds at the fault are lower on the coast than in the actual line of section. The amount of throw may be about 150 feet. The thickness of the Purbecks in Durlston Bay is variously estimated. Mr. Bristow's vertical section gives 370 feet.

The advantage of commencing at this spot consists in being able to work up the entire sequence in ascending order from here to Peverel Point, the very lowest beds alone being concealed. Professor Morris gave a sketch of the fauna and subdivisions of the Purbecks, together with a notice of the physical conditions which, in all probability, accompanied the deposit, and a comparison of these beds with the Purbecks of other areas. He especially dwelt upon the change from fresh water to marine conditions, showing that, although the change from marine through brackish to fresh water is gradual, the change from fresh water to marine conditions was abrupt, indicating, as it were, sudden inroads of the sea. He also ventured to call in question the absolute change of species said to occur in the three subdivisions of the Purbecks. The remarkable vertebrate fauna was then alluded to, and special description given of the mammalian remains discovered by Messrs. Beckles and Brodie, and described by Prof. Owen and Dr. Falconer. Up to the year 1856 Mr. Beckles had collected 28 individual and Mr. Brodie seven individual specimens—35 in all, and these consisted of fourteen species, mostly insectivorous marsupials, though one (*Plagiaulax*) was believed to be an herbivorous quadruped allied to the kangaroo-rat (*Hypsiprymnus*).

The members then distributed themselves along the beach, but always making some progress towards Peverel Point. Species of *Cypris*, some tuberculated, others not, were discovered, together

with specimens of *Serpula coacervata*, *Melania*, *Paludina*, *Planorbis*, *Cyclas*, *Cyrena*, &c., and in the more marine bands, *Pecten*, *Modiola*, *Corbula*, *Ostrea*, &c. The Lower Purbecks are remarkable for immense concretionary masses of gypsum; they contain no workable stone. At the base of the Middle Purbecks occurs a sort of marly dirt bed a few inches thick, in which the mammal bed is found. There was some difference of opinion as to which was the real bed, but this was finally settled to the satisfaction of all parties. The Middle Purbecks are, on the whole, the most interesting and valuable. They contain five workable beds of stone. Three of these are above the Cinder Bed. Two are below. The following is the order of their occurrence :—1. The Laning Vein. 2. The Freestone Vein. 3. The Downs Vein—the Cinder, a thick bed of *Ostrea distorta* and other shells. 4. The Cap and Feather. 5. The New Vein. Remains of turtle and fish are frequently found in these beds by the workmen. The base of the Upper Purbecks is characterized by the Burr Beds—not now worked—near Swanage. Above these are the *Unio* beds, and in this series occurs the Crocodile bed—a blue-hearted, gritty limestone full of skin and teeth and other remains of *Goniopholis crassidens*, together with wood, fish palates, turtle. &c. Abundance of fragments were secured. With the *Paludina*-beds (Purbeck marble) of Peverel Point this most interesting ascending section terminates. There is a good deal of complex folding here, and the principal rock beds are thrown into a synclinal, which may have the effect of strengthening the Point, and thus saving the town of Swanage.

In the afternoon the party walked along the shore of Swanage Bay, hurrying past the Hastings-Wealden beds, which, though said to be 1,800 feet thick, are but poorly fossiliferous. Variegated clays and sands, dipping northwards at an angle which increases as the chalk is approached, are the chief features. Bones of *Iguanodon* have rolled out of them occasionally.

There was a two-fold reason for this haste. Firstly, a large portion of the party wished to catch the up train from Wareham. Secondly, it was felt that the centre of interest lay in Punfield Cove, not only because of the discussion between Messrs. Judd and Meyer as to the so-called Punfield Beds, but because the monotonous character of the strata undergoes a considerable

change at this place, and the beds immediately underlying and at the base of the chalk possess features of considerable interest. The beds involved in the Punfield controversy, including what Professor Judd allows to be "Upper Neocomian," are over 200 feet thick (these are all included in the upper part of *k* 1 of Mr. Bristow's section). The Gault cannot be measured; the Upper Greensand, according to Fordham, is 70 feet thick, the Chloritic Marl 4ft., the Chalk Marl 40ft., the grey Chalk 100ft. The dip is for the most part about 65° towards the N.

The party being assembled in full view of the Punfield section, at the most convenient spot for noting the somewhat obscure features of the cliff, the Directors first gave a brief history of the controversy on the Punfield Beds, and, secondly, endeavoured to point out the various horizons which are mentioned in the writings of Messrs. Judd and Meÿer, so that afterwards each horizon might be separately examined and identified. The latter task proved the more difficult of the two.

As regards the points in dispute, Mr. Meÿer observes that he and Prof. Judd agree in the main as to the stratigraphy, though in a second paper he supplements his section with some important details. The sequence below the Gault is somewhat as follows in descending order:—

	ft.	in.
1. Grey Clays alternating with ferruginous sandy beds. *Exogyra sinuata*, *Panopea neocomiensis*. "Upper Neocomian"	60	
2. *The Cypridiferous Beds with their bands of Limestone made up of* CYRENA, OSTREA, *&c. Not seen either by Judd or Meÿer*	? 6	
3. Ferruginous sands with interlaminated clays and lignite, in the middle several bands with oyster and other marine shells	153	
4. "The marine band of Punfield," with a rich and novel fauna, representing, according to Meÿer, in common with the rest of the Punfield Beds, three elements, viz:—(1) A set of marine or brackish water mollusca peculiar to this locality and to the coal-bearing strata of Eastern Spain. (2) About four species of brackish water molluscs, a *Cardium*, a small *Ostrea* and *Corbula* or *Potomomya*, and a species of *Mytilus*. (3) A group of fossils common in the Neocomian Beds of Atherfield and Shanklin	1	9

With the marine band, according to Prof. Judd, the Punfield series terminates, being succeeded in descending order by the Variegated Beds of the Wealden. But Mr. Meÿer has obtained abundant indications of marine shells a long way below this, and he places 100 feet of beds between the Marine Band and the Variegated Beds of the Middle Wealden. Continuing the section downwards. we have, according to Meÿer—

5. Blue Clay with *Arca* and Marine Crustacean (Atherfield "lobster")
6. Band containing abundance of Lower Greensand fossils.
7. Blue Clay which may be on the horizon of the *Perna*-bed at Atherfield.
8. GRIT-BAND associated with *Cypis* and remains of small fish.
9. Blue cypridiferous shales and clays of the UPPER WEALDEN, for the most part masked.

The difference of opinion between Prof. Judd and Mr. Meÿer amounts to this—the former regards the beds between the admitted Upper Neocomian and the Variegated Wealden as a "fluvio-marine" series, having certain analogies with the coal-bearing beds of Utrillas, in Eastern Spain. Mr. Meÿer, on the other hand, regards the whole as a littoral facies of the Lower Greensand, and he prefers to place them on the horizon of that of the Isle of Wight rather than correlate them with any portion of the underlying series as developed in that island.

The second duty of the Directors was to identify the several horizons detailed in the preceding section. This was not quite so easy a task. Mr. Meÿer's *grit-band* was seized upon as a datum line, and from this line upwards the investigations were carried. That portion of the party bound for Wareham had to be satisfied with a rapid scamper across the strike, and hasty identification of the beds as far as the Upper Greensand. This was effected under circumstances of some difficulty, but on the whole the general sequence and character of the beds was fairly made out. Those who had more time at their disposal then returned to the datum line, viz., the Grit-band which stands out well in the slippery cliff. In order to do the thing thoroughly, coats were taken off, and relays of members took their turn at the diggings until a considerable trench was formed. It was then found that the accumulation of material sliding forwards precluded all further investigation without heavier tools and more systematic action, such as there was no time to apply. The Grit-band dips northwards at

about 65°, and the overlying beds are strictly conformable. Subjoined is an account of the section cleared, which may be deemed fairly accurate as far as it goes. From above downwards :—

BASE OF THE PUNFIELD SECTION.

	ft.	in.
F. Clays with abundance of marine fossils	1	9
E. Ironstone nodule	0	6
D. Upper black *Cypris*-Clay, with more of the tuberculated forms than in the lower beds	2	7
C. Banded and variegated greyish sandy clays. Unfossiliferous	4	3
B. Cypridiferous black clays with two species of *Cypris* ...	0	9
A. GRIT-BAND; a lime-bound quartz grit with fragments of bone. Shales and clays of the UPPER WEALDEN.		
Total measured	9	10

It is evident, therefore, that a Wealden fauna extends above the Grit-bed to a higher point than supposed by Meÿer. The nodule line, E, represents the junction bed between the Wealden and Lower Greensand fauna. How far the top of this fauna lies below the original "marine band" the members had no means of judging.*

These operations took up so much time that the contemplated walk across Ballard Down to Studland Bay had to be deferred to another opportunity, and thus the original programme for the second day was incompletely carried out, both as to its commencement and termination.

* It has quite recently come to my notice that there is, in the British Museum, a very fine specimen of a *Vicarya*, forming part of a collection from the Isle of Wight. The shell is in good condition, and probably came from Atherfield. It is placed amongst the Lower Greensand fossils of that locality.—W.H.H.

ORDINARY MEETING.

FRIDAY, JUNE 2, 1882. W. H. HUDLESTON, ESQ., MA., F.G.S., PRESIDENT, in the chair.

The donations to the Library since the last meeting were announced, and the thanks of the Association returned to the donors.

The following were elected members of the Association:—J. M. Sutherland, Esq.; W. H. Holthum, Esq.; Geo. Bennett, Esq.; A. S. Ormsby, Esq., M. Inst. C.E.; W. B. Jeffrey, Esq.; G. J. Millar, Esq., B.A., Herbert Taylor, Esq.; Stanley Cork, Esq.; Wm. Topley, Esq., F.G.S.; Corn. Robbins, Esq.; Alf. Nicols, Esq.; S. P. Newcombe, Esq.; and G. T. Barham, Esq.

The following paper was then read:—

"On a New Section in the Thames Valley." By J. Logan Lobley, Esq., F.G.S.

ON A NEW SECTION IN THE THAMES VALLEY.

BY J. LOGAN LOBLEY, F.G.S.

The dearth of natural and the scarcity of artificial sections in the neighbourhood of Windsor, and the peculiar geological structure indicated by the inlier of Chalk on which the Castle stands, give to any new section shown by a well-sinking or a well-boring in that locality considerable value. I have, therefore, thought a brief description of an experimental boring now being made for the Slough Waterworks Company, near the village of Datchet, opposite to Windsor Castle, and within a mile from the Chalk of the Castle Hill, might with advantage be brought before this Association, which interests itself so much with the geology of the Home Counties.

I am indebted for the details of the section to E. O. Secker, Esq., C.E., under whose direction the boring is being made, and, who has very courteously given me the particulars which had been recorded by him. He has likewise placed at my disposal the box of specimens of the beds passed through, now lying on the table.

The boring is being made with one of Mather and Pratt's machines, the boring augur being 3ft. in diameter, worked by manual power. Cores such as those brought up by the Diamond boring process cannot be obtained by this machine, still, quite good specimens of the beds passed through are brought to-day; and for moderate depths and soft strata this system seems to be well adapted. At the Slough Waterworks a boring of 26in. diameter to a depth of 479ft. 3in., commencing at the bottom of a well sunk 107 feet, was completed in four months, by one of these machines, worked by steam power.

The low plain overlooked by the Royal Castle, and through which the river Thames winds between the counties of Berks and Bucks, consists, immediately below the surface soil, of extensive sheets of Brick-earth and gravels of Post-Pliocene Age, to which the name River-Drift is often given. These valley deposits are of varying thickness. Opposite Slough Station a freshly cut railway section shows Brick-earth of about twenty feet in thickness, overlying about 14ft. of gravels; while on the opposite side of the town, on the Slough and Eton road, a temporary road section gave only about a foot of Brick-earth on the top of the London Clay. The Brick-earth is extensively worked for brick-making in the neighbourhood of Slough, along the Great Western Railway, and is the source whence a large proportion of the bricks used in London is derived.

The Post-Pliocene deposits rest either upon the London Clay, upon the Reading Beds, which extend beyond the London Clay like a fringe, or upon the Chalk along a line of country westward from Windsor. The new Geological Survey Surface Map of the London District, and sheet 7 of the old Survey Maps, show these geological conditions very plainly.

The previously mentioned Slough Waterworks well, at the west end of that town, was sunk through 24ft. 6in. Post-Pliocene valley deposits, 20ft. 6in. of London Clay, and 41 feet of Reading beds, reaching the Chalk at 90 feet. A well at the Royal Nursery, Slough, sunk in 1823, and mentioned in Whitaker's "Geology of the London Basin," gives 27 feet Brick-earth and gravel, 31 feet of London Clay, and 36 feet of Reading beds, with the Chalk at 94 feet. There does not appear to be any record of a well-sinking or boring between Slough and the river where the Chalk immediately underlies the valley deposits, and on the other side of which this

formation rises, in the bold elevation on which Windsor Castle stands, considerably above the valley level.

It will be seen from what has been just stated that the present boring has a special significance as giving with certainty the depth of the Chalk, and the thickness of the Tertiary beds, where previously they could only be inferred. The inference from the facts previously known is shown by sheet 74, of the Geological Survey Horizontal Sections. This inference, briefly stated, is that the Chalk from Slough gradually rises and approaches the surface until it shows itself at Windsor, and that the Tertiary beds correspondingly diminish in thickness, gradually losing their upper portions, so that as the river is approached we lose the London Clay, and have only the Reading Beds over the Chalk, with, of course, the valley deposits as a capping. It would follow from this deduction that the Chalk would be at Datchet less than fifty feet from the surface, and the Reading Beds about 30 feet thick, with no London Clay between them and the gravels.

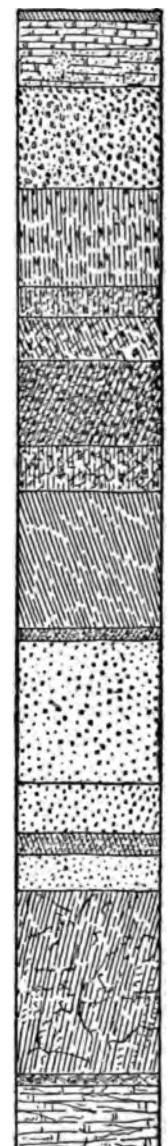
The boring now brought under notice gives the following section leading to an important difference in our conclusions. (See next page.)

Beds 5, 6, and 7, have all the appearance of London Clay, and the remaining beds down to the flints above the Chalk may, perhaps, be safely considered to be Woolwich and Reading Beds, since Bed 8, being a good example of Mottled Clay, may be taken to mark the commencement of that series.

These results would seem to point to the existence of a fault between Slough and Windsor not hitherto recognised. If this be so, the fault must be very near to the boring, as the Chalk is mapped at a furlong distance.

The Chalk of Windsor being surrounded by newer beds is a good example of an inlier, and forming, as it does, a hill of considerable elevation, it is concluded that it has been the result of an upheaval. The Chalk is known to be near the surface at Pinner, below what is called the Pinner Inlier of the Woolwich and Reading Beds. Again at Northaw, in Hertfordshire, we have an inlier of Woolwich and Reading Beds, with a centre of Chalk. Now the Windsor Inlier, the one at Pinner, and that at Northaw, are in one straight line. It would, therefore, seem probable that the three inliers have been produced by the same upheaval acting along a line from Windsor to Northaw. That such an up-

SECTION OF BORING AT DATCHET.



			ft.	in.
Post-Pliocene.	1	Surface Soil	1	0
	2	Brick Earth	3	0
	3	Brick Earth, more Sandy	3	6
	4	Valley Gravels with Sand	11	6
London Clay.	5	Blue Clay	12	0
	6	Blue Sandy Clay	3	0
	7	Blue Clay	5	0
Woolwich and Reading Beds.	8	Red and Yellow Mottled Clay	9	0
	9	Blue and Brown Mottled Clay	5	0
	10	Brown Clay	14	0
	11	Yellow Sandy Clay	1	0
	12	Brown Sand	16	0
	13	Dark Sand	4	0
	14	Sandy Clay	2	0
	15	Light Sand	3	0
	16	Mottled Clay	23	0
	17	Flints	1	0
		CHALK		
			117	0

heaval would be productive of dislocations is more than likely, and I venture to think that one of these has been found at Datchet. That very important dislocations have taken place in the Thames Valley, the Members of the Geologists' Association well know, from their repeated visits to the neighbourhoods of Woolwich and Erith. In this part of the valley the Chalk is thrown down below the marshes to a very considerable depth by a fault running east and west for miles. It has not, however, been traced further west than the vicinity of Sydenham.

As a matter of general interest, I may add that the Datchet boring obtained water at 3 feet from the surface, and when I last saw it water was flowing from the top with the boring rods down. Mr. Secker informs me that at the Slough well and boring the water rose to within 7 feet from the surface, and when pumped down the well yielded 40,000 gallons an hour, the water rising to 60 feet from the surface. These facts are of great public importance, since they show the immense storage of water that exists at a moderate depth below the surface of the Thames Valley.

EXCURSION TO HAYWARD'S HEATH AND DITCHLING BEACON.*

(SOUTHERN VALLEY OF THE WEALD.)

SATURDAY, JUNE 10TH, 1882.

Director : J. LOGAN LOBLEY, ESQ., F.G.S.

(*Report by* THE DIRECTOR.)

The third of the Weald series of Excursions along the line of section between London and Brighton was devoted to the district between Hayward's Heath and Ditchling Beacon (the summit of the eastern section of the South Downs) comprising the southern Weald Clay vale.

The ground crossed is similar, therefore, geologically with that traversed between Redhill and Three Bridges on the 6th of May, but with the difference that the succession of Beds is reversed. One of the minor Wealden anticlinals occurs at Hayward's Heath, where brickyard sections show Cuckfield Clay at the surface, the ground is then formed of Tunbridge Wells Sands nearly to Wivels-

* Third of the Weald Series.

field, where a depression on Weald Clay is met with. This is, however, very narrow, and Wivelsfield itself stands on what may perhaps be called an outlier of Hastings Beds, but which joins on to the main mass a little to the east. This is soon crossed, and then the Weald Clay vale is reached. Ditchling Common is a very extensive tract, entirely on the Clay, which here forms ground more or less undulating, the highest part of the common having a considerable elevation. A divergence from the line of section was here made to enable the party to visit the very extensive brickyards near Keymer Junction. The proprietor, Mr. Johnson, very courteously conducted the party to the kilns, to the excavations and to the terra cotta showrooms, giving full explanations to his visitors. The section of the Weald Clay here seen is one of the best in the entire Wealden area, exposing the Clay as it does to the depth of some fifty feet. The Clay at this place is used solely for brick making, the terra cotta being made at Ditchling Pottery, about a mile distant, from a finer clay close to the surface of the highest part of the Weald Clay ground. To this pottery the party then proceeded, and the beautiful and interesting process of terra cotta manufacture was explained to them by the manager of the works. After an inspection had been made of the Clay, *in situ*, the southern part of the common, was traversed, and as the village of Ditchling was approached the changed character of the ground indicated the presence of the Greensand, and at the village itself a section of the Folkestone Beds was found behind the hotel. The ancient church stands on a small hill of these Beds. The party dined together at the Bull Hotel, when Mr. Hawkins Johnson expressed the thanks of the Members to the Director in some clever extempore verses, and then the geologists continued their journey southwards and soon reached the foot of the Downs. There does not appear to be any representative of the Atherfield Clay in this neighbourhood, but the Hythe Beds, the Sandgate Beds, and the Folkestone Beds are present, though forming features comparatively insignificant when compared with the Lower Greensand elevations which fringe the North Downs. The outcrop of the Gault, too, is narrow. It is indicated by the dark colour of the ploughed land above it, locally called "Blackland." The Upper Greensand also is soon crossed at the base of the hills, and the Grey Chalk is shown by fine sections at a little elevation. Continuing the ascent the higher beds of the Chalk are successively passed over until the summit of the Downs is reached,

consisting of a bed of the Upper Chalk with flints. Ditchling Beacon is 814 feet above sea level, and as it is the highest point in the Sussex Downs, it affords a magnificent view on all sides. The Southern Valley of the Weald crossed during the day was looked over to the north, while to the south the view extended across the Downs and far out to sea. A route due west along the summit of the Downs was now taken, and a descent made near Coombe Down, when a visit was paid to the new waterworks, where a deep well has been sunk through the Lower Chalk. Passing through Keymer village, at which a section of the Folkestone Beds was seen, the party hastened to Hassock's Station for the return journey to London.

EXCURSION TO RICKMANSWORTH.

SATURDAY, JUNE 17TH, 1882.

Directors: WILLIAM WHITAKER, ESQ., B.A., F.G.S., and JOHN HOPKINSON, ESQ., F.L.S., F.G.S.

(*Report by* THE DIRECTORS.)

The Harefield Chalkpits, close to the river Colne below Rickmansworth, expose as fine sections of the Upper Chalk as any to be met with on the northern side of the London Basin, and nowhere can better examples of "pipes" in the Chalk be seen than in one of these pits, while the absence of any vestige of a pipe in the other affords an instructive lesson in physical geology. But scant notice, however, of these sections has hitherto been taken.

To examine these pits, and also sections of the Tertiary beds at Woodcock Hill, the members of the Association assembled at three o'clock at Rickmansworth station, where they were met by members of the Hertfordshire Natural History Society, the united party numbering between forty and fifty.

After leaving the station the first place visited was an old chalkpit on Stocker's Farm, of such little interest that it merely elicited from Mr. Whitaker the observation, "Ladies and gentlemen, this is a chalkpit."

Proceeding down the valley of the Colne, a short walk along the towing-path of the canal brought the party to the first of the large chalkpits to be visited, on the left bank of the river. The Upper Chalk here is bare, and of a pure white, the clayey beds which

come on just above having thrown off the water falling upon them, thus preventing it from percolating into the chalk and giving rise to pipes.

The next pit, a field's length farther south, by the old "Copper Mills," which have long ceased working, was soon reached, and formed the principal point of interest. Here the whole section of the chalk, which presents an almost vertical cliff from 90 to 100 feet high, is irregularly capped by gravel, from which pipes, often of most fantastic shape, and of roughly cylindrical form, extend downwards to distances varying usually from 30 to 70 feet. A mass of white chalk, of such a height and extent as, but for these pipes, would here have been exposed, would have had a most dazzling appearance; but the whiteness of the chalk is subdued by the darker colour of the pipes, which appear to occupy almost as much space on the surface of the vertical sides of the pit as the chalk itself.

Here Mr. Whitaker, mounting a tilted truck, explained the mode of origin of these pipes. They were, he said, holes or hollows in the chalk filled in by gravel or sand from the beds above. In old books they were sometimes stated to have been formed by sea-action, but such was not the case. They were caused by rain, which, in passing through air, absorbed carbonic acid, a gas which, in solution, had the power of dissolving the hardest limestone. The water, charged with carbonic acid gas, sunk down through some line of weakness in the chalk, along which it gradually dissolved the rock, until at last the overlying gravel and sand sank into the cavity thus formed. Here and there a mass of gravel was to be seen, which appeared to be unconnected with the pipe immediately above it, this appearance being due to the chalk not always having been worn away in a vertical line, so that the connecting link of the pipe was not to be seen; and this was the explanation of the apparently isolated masses of gravel frequently seen in the chalk. Where there was a mass of Tertiary clay on the chalk, there were generally no pipes, for the clay being impermeable prevented water from getting through into the chalk; whereas water percolated through gravel, forming these pipes, in which might frequently be seen angular chalk-flints, not worn at all, and nearly in the position they occupied before the chalk in which they were embedded was dissolved away. The gravel here, Mr. Whitaker stated, forms part of a high terrace that occurs over

the plateau above the pits, hiding the junction of the old Tertiary beds and the chalk, and it is supposed to be of Glacial age, because it is like other gravels near which run under the Boulder Clay; for such detached masses of gravel were presumed to be of the same age as the larger masses, of which they seemed to be outliers.

After a pleasant walk across the fields the party arrived at the Woodcock Hill Kiln. Here the section exposed was found to be better than when noted by the Geological Survey some years ago, the beds now seen in the upper pit being as follows:—

Clayey gravel, resting in hollows in the bed below.	
Basement-bed of the London Clay.	Brown and grey sandy clay, with a ferruginous bed in which a cast of Panopæa was found. ? 5 feet.
	Line of flint-pebbles.
	Brown loam, about 3 feet.
Reading Beds.	Mottled plastic clays, thick.

A lower small pit showed about ten feet of brown sand, with clay above, and some apparently in it. This sand also belongs to the Reading Beds, and must dip under the mottled clays. The surface of the sand was very hard from exposure. The gravel is apparently part of the same bed as that on the top of the chalk near Harefield. This section presents a rather unusual feature in a pebble-bed in the midst of the basement-bed of the London Clay, and none at the bottom. The mottled clays below, Mr. Whitaker stated, were unfossiliferous, there being nothing like them at Woolwich, &c., where the Woolwich beds contain many kinds of fossils.

In crossing the fields from Woodcock Hill to Rickmansworth, on the summit of a hill from which was obtained an entensive view, embracing the valleys of the Colne, Chess, and Gade, a bed of pebbly gravel was examined. This, Mr. Whitaker said, must be as old as Middle Glacial, and might be older than Glacial, and he pointed out the difficulty, and sometimes the impossibility, of definitely fixing the age of such isolated masses of gravel. We have here the usual features of a gravel-capped hill—a flat top and a steep slope. The stones are nearly all water-worn, not angular, mostly of flint, but some of quartz.

From Rickmansworth station the train was taken to Watford, Dr. A. T. Brett having kindly invited the party to tea at his residence, Watford House. Refreshments were served under a large tree on the lawn, after which votes of thanks to Dr. Brett and to the Directors were proposed and heartily responded to.

EXCURSION TO THE DENEHOLES OF BEXLEY.

JUNE 24TH, 1882.

Directors: F. C. J. SPURRELL, F.G.S., and T. V. HOLMES, F.G.S.

(*Report by* T. V. HOLMES.)

On reaching Bexley the party at once proceeded to Stankey Wood, on the east side of Baldwyns, the proprietor of which, J. G. Hepburn, Esq., had kindly given permission for the descent into one of the pits. While the members of the party were being gently lowered one by one into the selected cavern, those still above ground occupied themselves in examining the surrounding surface, and in listening to and questioning the Directors on the subject of Deneholes.

The word Deneholes is old English; it signifies *den*holes, and is pronounced *d*aneholes. Though mentioned by Camden, Lambarde, and Hasted, deneholes have been strangely neglected in the present century, Mr. F. C. J. Spurrell being the only scientific observer who has made a long and careful study of them. They are, therefore, little known, though almost all geologists and anthropologists know more or less about pits of the Grimes Graves and Cissbury class. Deneholes, indeed, owe the slight notoriety they have recently acquired to various paragraphs in the "Times" and other newspapers, in which they were alluded to last year as a possible cause of the subsidences at Blackheath; and, on the other hand, to the reading of Mr. Spurrell's important paper on them at the Royal Archæological Institution, on April 7th, 1881, and to the Report of the Blackheath Subsidence Committee, about three months later. Consequently this year the Bexley Deneholes have been visited both by the Geologists' Association and by the Lewisham and Blackheath Scientific Association, while those at Hangman's Wood, near Grays, north of the Thames, have twice been the scene of an excursion of the Essex Field Club. The last named Society proposes to make a thorough examination of the Essex Deneholes next year.

Denehole shafts are of very various depths, and the caverns, at their base vary much in size and plan. The shafts are from 2ft.

6in. to 3ft. in diameter, where they have suffered but little from the weather, and are perfectly cylindrical in shape. They especially abound in the neighbourhood of Bexley and Crayford in Kent, and between Purfleet and East Tilbury, in Essex. In Stankey Wood, and at Cavey Spring, near Bexley, great numbers are concentrated in two or three acres of ground, while single pits are scattered here and there in addition. The majority are, however, not now open, their position being indicated by basin-shaped depressions varying in depth from 5ft. to 15ft. or more.

The descent into the cavern being slow and gentle allowed the visitor to notice the narrowness of the shaft and the presence of the footholes in its sides, by means of which its original excavators had ascended and descended. So little enlarged is the shaft in the selected Denehole (No. 2, in Pl. II. of Mr. Spurrell's paper) that, on the occasion of the visit of the Lewisham and Blackheath Scientific Association, two of the visitors ascended about 20ft. and descended again by means of these footholes. The upper 40ft. of this shaft is in Thanet Sand, the rest being in Chalk. Its sides are coated by moss, which has tended most efficiently to prevent denudation. At the bottom of each Denehole shaft is a conical heap of sand and *débris*, with occasionally the skull or bones of some unfortunate dog or sheep which has fallen down the shaft and perished. The marks made by the claws of dogs, which had vainly tried to get out by climbing the sides of the caverns were abundantly visible in this one up to a certain height.

Though the shaft of the selected Denehole was, as we have seen, in excellent preservation, the cavern itself had suffered much from downfalls of chalk and Thanet Sand from the roof. These tended much at first sight to obscure its plan, which became evident only by degrees. The shaft entered the centre of the chamber, and admission to it was given by means of two openings in opposite sides of the shaft, the chalk at right angles to the direction of these openings being left in the form of two pillars supporting the roof. The cavern would at first consist of two chambers in the same straight line, the result of the enlargement and prolongation of these openings. Then chambers at right angles to them would be added at similar distances from the shaft and on each side of it. The cavern would then be six-chambered. And by increasing the breadth of these chambers, except just at their mouths, the partitions between them would disappear, six pillars between their

former entrances remaining. This would have been the final state of the Denehole descended, but that its original excavators, having apparently needed increased and undivided space, removed the two pillars on one side of the shaft, and caused the downfall already mentioned. The downfall was, possibly, to some extent, due also to the thinness of the chalk roof, which was only about 2ft. 6in. thick. The dome, mainly in Thanet Sand, resulting from the downfall in this part of the cave, is so beautifully regular in shape as to look at first sight like a work of design. The greatest diameters of this cavern were found by Mr. Spurrell to be 49ft. by 38ft., and the height about 25ft.

The shafts in Stankey and Cavey Spring are all mainly in Thanet Sand, capped, at the former place, by two or three feet of Dartford Heath gravel. It is evident that these Bexley Deneholes differ from pits of the Grimes Graves class, and from those at Cissbury in many fundamental particulars. The shafts at the latter places are large in diameter, and broader at the top than at the bottom, whence low galleries 3ft. to 5ft. high, or thereabouts, proceed in various directions along the line of a particular flint band, and connect the various shafts. The Deneholes, on the contrary, have narrow cylindrical shafts of very small diameter, terminating in lofty chambers about 15ft. to 25ft. high, which never communicate with adjoining caverns, though they are often very close together. The nearest cavern to No. 2, Stankey, for example, is only separated from it by a thickness of about 10ft. of chalk, yet no attempt has been made to unite them. And, as regards geological position, shafts of the Grimes Graves class are wholly, or almost wholly, in chalk, while these Bexley Deneholes are concentrated in spots where there are from 40ft. to 60ft. of overlying beds above the Chalk. Yet there is a broad expanse of bare Chalk less than a mile eastward of Stankey and Cavey Spring.

All those of the party who wished to do so having descended into and emerged from the cavern, Mr. Spurrell led the way to Jorden's Wood, a few hundred yards away, in which there are ancient entrenchments and other works, marking the site of an ancient village. A square camp, Roman in plan, and in which coarse Romano-British pottery has been discovered, was shown to have been placed over earlier works belonging to this village, the pre-existence of which has somewhat modified the shape of the

camp. Denehole shafts were seen here and there in the wood. Many flint flakes and implements have been found from time to time in this wood and the neighbourhood generally. This camp and the works close to it are on Thanet Sand.

The party then proceeded across Dartford Heath to Dartford, passing by the way some excavations for Dartford Heath Gravel and a chalk-pit. On arriving at Dartford some members partook of refreshment at the Black Bull Hotel, while others started for London by a train then nearly due.

It must be mentioned, in conclusion, that to Mr. Spurrell the Geologists' Association is indebted, not only on account of his services as Director, but also for all the trouble involved in making the arrangements for our descent.

EXCURSION TO CROYDON.

SATURDAY, JULY 1, 1882.

Director: H. M. KLASSEN, ESQ., F.G.S.

No report of this excursion, attended by over 70 members, has been received.

ORDINARY MEETING.

FRIDAY, JULY 7, 1882.

W. H. HUDLESTON, ESQ., M.A., F.G.S., PRESIDENT, in the Chair.

The donations to the Library since the last meeting were announced, and the thanks of the Association returned to the donors.

The following were elected members of the Association:—

Miss Helen Banter; Wm. A. Forbes, Esq., B.A., F.G.S.; R. A. MacBriar, Esq., Assoc. Inst. C.E.; H. W. Moncton, Esq.; Geo. Niven, Esq.; Dr. Fred. Shepherd, M.R.C.S.; W. E. Small, Esq.; and Thos. Stewart, Esq.

The following paper was then read :—

NOTES ON THE GEOLOGY OF CUMBERLAND NORTH OF THE LAKE DISTRICT.

BY T. V. HOLMES, F.G.S.

A glance at Greenough's or Ramsay's "Geological Map of England and Wales" shows the Silurian, or Lake Country, to be surrounded by rocks of Carboniferous age. These, in their turn, are enveloped by Permian or Triassic beds; on which, again, a little west of Carlisle, reposes a small outlier of Lower Lias. I shall confine my attention this evening mainly to the Carboniferous and overlying rocks of the district due north of the Lake Country.

The visitor to the Lakes, who obtains his first impressions of the country to the north from the top of Skiddaw, is likely to have an exaggerated notion of its flatness, as the height at which he stands makes even the limestone fells look low. Nevertheless, the Carboniferous Limestone in more that one place attains a height of over 1,200 feet above the sea, and is mainly to be found above an altitude of 500 feet. But as the ground slopes down gently from the mountains to the Solway, the Upper Carboniferous and Permian beds occupy lower and lower levels. Though a considerable amount of Glacial Drift obscures the Carboniferous Limestone, the area of ground covered by drift increases very much as we approach the Solway. At heights of 500 feet and upwards it is seldom that the influence of the underlying rocks on the shape of the ground is not in some degree perceptible. But at lower levels, not only is the ground persistently drift-covered, but the surface ridges usually appear to be entirely formed of drift, and without any core of harder rock below. Near Abbey Town the thickness of Glacial Drift pierced in a boring was very nearly 200 feet. This was probably exceptional, but the experience of well-sinkers combines with the evidence derived from brooks and railway cuttings to show that most of the Permian ground towards the Solway is persistently covered by an average thickness of from 30 to 40 feet at least.

The close of the Upper Silurian period was (as the late J. Clifton Ward has pointed out in his "Lake Country Memoir") marked by "gradual upheaval and unprecedented denudation." No deposits were added, but immense thicknesses of strata were carried away and deposited elsewhere, the Upper Silurian and a large part of the

Volcanic series being thus removed from the northern part of the Lake district. Resting sometimes on Skiddaw Slates, sometimes on Upper Silurian rocks, is the lowest rock with which I have to deal—the conglomerate, formerly considered to be of Upper Old Red Sandstone age, but now styled by Ward and others the Carboniferous Basement Bed. This rock is best represented in the conical hill known as Great Mell Fell, which stands out conspicuously a little south of Troutbeck Railway Station, and attains a height of 1,760 feet above the sea. Ward remarks that the stones of the Mell Fell conglomerate are almost all micaceous sandstone, which Mr. Aveline has identified with that of the Upper Silurian (Ludlow) of the southern part of the Lake District, but that some stones in it may belong to the Skiddaw slates. He also notices the local variations of the conglomerate, and says that probably, after the removal of an enormous mass of rock in the Mell Fell area, facilities were given for the northward drifting of materials derived from the Upper Silurian rocks, while the neighbouring Skiddaw slates and Volcanic rocks were comparatively protected from denudation. The reason for styling this conglomerate the Carboniferous Basement Bed, instead of referring it to the Upper Old Red Sandstone period, is, of course, to be found in the immense length of time the enormous denudation at the close of the Upper Silurian period must have occupied. In short, the Old Red Sandstone period, in this district, was one of denudation, not of deposition.

In its turn the Basement Conglomerate must have suffered much from denudation before the deposition of the Carboniferous Limestone. Its present distribution is extremely irregular. Though its existence may possibly often be hidden by the overlapping of the beds above it, or the presence of drift about their line of junction, it never, where seen north of the mountains, presents any conspicuous feature, but is only to be detected by careful search, as in the little river Ellen, south-east of Uldale, or in the Parkend Beck about Greenhead.

There is no evidence to show how far the Carboniferous Limestone once extended over the Silurian rocks. But as many of the limestones are very thick—that at Parkhead, N.E. of Caldbeck, being quite 200 feet—they must once have extended many miles southward of their present outcrops.

The country due north of the Lake Country does not possess those

aids to a knowledge of the Lower Carboniferous Beds that exist on the east of the Eden Valley, on the one hand, or in the Whitehaven and Cleator district on the other. For a coal of Yordale age, known as the "Little Limestone Coal," is regularly worked, both in the neighbourhood of Tindale Tarn, and eastward about Greenhead, Haltwhistle, and Hexham. And in the Whitehaven and Cleator Moor district are many pits in the limestone for the extraction of red hematite (ferric oxide). But about Caldbeck, Ireby, or Bothel, there are no hematite mines, and though here and there a thin coal has been worked for local purposes, no coal so important as the Little Limestone Coal is known to exist. To these negative disadvantages must be added the positive one of the presence of a very large number of faults, many of them apparently of importance; and lastly, the obscuring influence of the Glacial Drift. It thus never happens that any series of beds is shown clearly for more than a very short distance along either the dip or the strike.

The most common fossils in the limestones are Encrinites, usually of small size. Corals, however, are not uncommon, and some quarries, chiefly in the lower limestones, abound in a species of Productus.

Clints Crags, a little north of Isell Hall, near Cockermouth, are worth visiting on account of the remarkable way in which the limestone has been dissolved away along the lines of jointing, so as to leave spaces often quite large enough to admit a man's leg, and two feet or more in depth, between the surface blocks. These spaces being all green with vegetation, their depth must be ascertained by means of a stick. Other instances of this curious kind of erosion exist in the limestones of N.W. Yorkshire and elsewhere, but, so far as I know, Clints Crags furnish the best example in Cumberland.

The Carboniferous Beds may be described as hereabouts consisting of a great thickness—*possibly* 1,500 feet or more—of beds of limestone, sandstone, and shale, surmounted by an equal or greater thickness of sandstones and shales, with little or no limestone. Thin coals may be occasionally present on any horizon. Above these, again, are the true coal measures of the Whitehaven and Maryport Coal Field. North-east of Maryport this coal field appears to owe its shape and inland prolongation mainly to two great lines of fault. They both have a general N.E. and S.W. range, and a downthrow to the north-west. The more southerly

cuts off the Lower Carboniferous Beds, and brings in the Coal Measures, along a line a little north of Plumbland, Torpenhow, and Bolton Gate. The more northerly crosses the country from Maryport to, and beyond, Aspatria, and forms the Coal Measure and Permian boundary. I may add that the evidence for these lines of fault was obtained during the Geological Survey examination of the district, and the lines approximately fixed upon as the result of long and laborious work in the field have been here and there confirmed by colliery information. Though I have no doubt they are true in the main, very much more evidence than is available would be necessary before anything like accuracy could be attained, and there is too much drift to allow of more than a fair approximation, were the colliery evidence very much more copious than it is.

Perhaps the best course I can now take is to describe the route which would best repay a geologist who might wish to spend one day (at least) in the limestone fell district, and another in descending thence to the Permian area. A pleasant drive from Troutbeck station, with Blencathra and Carrock Fell on our left, and Greystoke Park on our right, brings us to Hesket Newmarket, and either at Hesket, or at Caldbeck, a mile and a quarter further on, the traveller may possibly get accommodation for the night, a convenience very rare in this district. Between Hesket and Caldbeck a steep, beautifully-wooded hillside bounds the view to the north, while southward the ground slopes gently down to the Caldbeck, which runs at the base of the wooded hill. Near the top of the wooded hill may be seen the farm known as Parkhead, about which a thick limestone is much quarried. The escarpment marking the outcrop of this limestone is visible below the farm-house, and beneath it the escarpments of two other limestones are perceptible, in spite of the trees. A descent from Parkhead to the Caldbeck, due south, would show that below the three thick limestones, whose escarpments may be seen from the Hesket and Caldbeck road, are three thin ones, interbedded with sandstones, shales, and two coals. Altogether more than 900 feet of rock exist between the Caldbeck and the top of the hill at Parkhead, and, as the dip is northerly, the slopes south of the stream consist of lower beds than those of the hillside on the north. But the spectator on the Hesket and Caldbeck road will also notice that the escarpments mentioned are traceable laterally for only about half a mile or thereabouts, and

will find sandstones and shales instead of these limestones between Parkhead and the village of Caldbeck; a fault having brought in higher measures to occupy the surface in their place. At Caldbeck the visitor should not fail to visit the Howk, where the water of the Caldbeck has made a passage through a thick limestone so as to leave a natural bridge above a waterfall. It is an extremely beautiful spot. The geologist will find that nowhere about Caldbeck is the succession of limestone rocks so clear as it is due south of Parkhead. It would be useless to give details of what may be seen here or there in areas of similar lateral extent. It will be best therefore to travel northward from Caldbeck, and descend Shawk Beck to the Permian Country at Curthwaite, on the Maryport and Carlisle railway.

On the common N. of Caldbeck are many signs of old surface workings for coal, and there are many also near Shalk (Shawk or Chalk) Beck, where it crosses the road between Caldbeck and Brocklebank. Thence as far north as East Curthwaite we have an almost perfectly continuous series of sections. Shalk Beck is, indeed, in this respect, unequalled, or even unapproached by any stream in this part of Cumberland. With the exception of two thin bands of limestone, a little below the house called Ninegills, the rocks seen south of the road from Near Welton to Rosley Rigg are Carboniferous sandstones and shales. Their dip varies much in amount; in direction it is from about 10 E. of N. to 10 N. of E., consequently, as we descend the stream, we traverse higher and higher beds. There is, however, a local exception to this rule. A fault ranges from Ninegills in a N.W. and S.E. direction, having a downthrow to the S.W., so that the beds immediately above Ninegills are higher than those directly below it. The lowest beds are therefore those just below Ninegills, on the upthrow side of the fault. These may be seen to be much paler in hue than the mainly pinkish or purple-grey rocks above and below them, and in these beds are the two limestone bands already mentioned. A purple-grey colour is very common in the Carboniferous sandstones and shales of this district, except in the case of those interbedded with the thicker limestones. These last are, usually, if not invariably, of the more characteristically Carboniferous brown or buff tints.

The experience of the geological surveyors in Cumberland has, so far, tended to establish the conclusion that though great thicknesses of pinkish or purple-grey Carboniferous rocks exist, they

never quite attain the brick-red tint of the Permian or Triassic beds. It would be an extremely difficult task to procure a good sized hand specimen of reddish Carboniferous rock from Shalk Beck, the Caldew, 'or elsewhere, that could be mistaken for Permian stone. When the outside of a piece of Carboniferous rock presents a brick-red hue, breaking it discloses a wholly purple-grey or pinkish interior, usually the former. But as colour itself must go for very little, of course a colour-test, such as I have given, derives all the weight it may possess, in cases in which it forms the sole available evidence, from its concurrence in other cases with more fundamental evidence. Through ignorance of this colour-test on the part of some of the older writers on the Geology of North Cumberland, many square miles of Carboniferous country, on both sides of Shalk Beck, at Westward, Rosley, and Sebergham, yet appear on geological maps as Permian. The origin of this error was, doubtless, the fact that the purple-grey rock, known as the Whitehaven sandstone, is seen in the cliff south of that town to rest unconformably on coal-measures of the ordinary brown or buff tints. It was accordingly considered to be "Lower New Red Sandstone," and rocks similarly coloured elsewhere were classed with it. But at Barrowmouth the Permian rocks are seen in their turn to rest unconformably on the Whitehaven sandstone, which appears to occupy the same position in Cumberland that is held by the Red Rock of Rotherham in Yorkshire.

We may now pursue our way down Shalk Beck. In the field north of the Rosley Rigg and Near Welton road, and on the left bank of the stream are numerous fragments of brick-red sandstone, from the water's edge upwards, and a small quarry may be seen in the higher part of the field. This rock is the uppermost of the two great Permian sandstones, viz: the St. Bees sandstone. The beds here seen are brought in by a fault, which has a range nearly E. and W., and a downthrow to the south, and crosses the beck a very few yards beyond the northern hedge of this field. The two next fields and the bed of the stream show rocks of purple-grey and lighter tints, but no brick-red beds. Then, as we begin to descend the path towards the bed of the stream—still keeping on its left or western bank—the brick-red Permian shaly sandstone, with a thin breccia at its base, is seen rising gently southward, and resting unconformably on other beds, mainly purple-grey, which occupy the bed of the beck, and have an easterly dip. The unconformity is again visible a few yards further on in the high bank at the next

sharp easterly bend, the same contrast of colour being again manifest. Above this point the shaly beds towards the base of the St. Bees Sandstone are succeeded by the more massive stone of the higher beds, and many quarries appear. (See Section 1.)

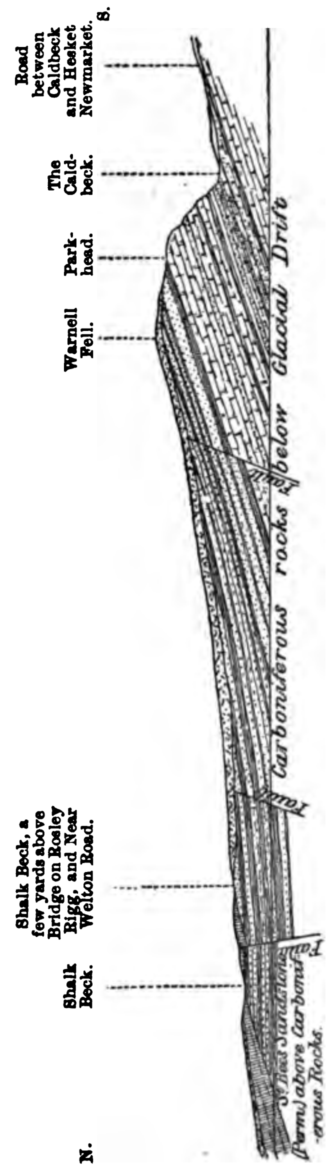


Fig. 1. *Diagrammatic Section from Shalk Beck, above East Curthwaite (N.), across Warnell Fell (S.). Distance, about six miles.*

We have now arrived on the borders of the (mainly) brick-red rocks, which occupy a large area on both shores of the Solway, in the Eden valley district, and on the coast at and south of St. Bees Head. In calling them Permian and Triassic, I do not wish to be understood as using those terms to signify more than relative position and (local) affinity. For it seems to me highly improbable that a classification which separates so widely rocks alike both as regards the circumstances of their original deposition and their lithological character can long stand.*

I learn from Mr. J. G. Goodchild that many changes appear in the Permian rocks of the Eden valley district as we journey from the south northward. Not only do they thicken very remarkably towards the north, but their lithological character alters also. The general nature of

* The sketch map, appended to my paper, on "The Rocks of the Carlisle Basin" ("Quart. Jour. Geol. Soc." May, 1881,) will be found useful in showing the distribution of the Permian and overlying rocks.—T. V. H.

these changes may be briefly shown. The following are some of the results of Mr. Goodchild's investigations as to the thickness and character of these rocks along lines across the Eden valley district; the first section being south of Appleby, the second about seven miles S. of Carlisle.

HILTON BECK, S. OF APPLEBY.

	feet.
St. Bees Sandstone	500
Red Shales, &c.	250
Magnesian Limestone	15
Plant Beds, with thin bands, Mag. Lst. and impure coal	40
Lenticular Breccias, with Red Sandstone	150
False-bedded Red Sandstone (Penrith)	300
Lower Breccias	100
	1,355

SOUTHWAITE RAILWAY STATION TO NEWBIGGIN.

St. Bees Sandstone...	1,500 to 2,000ft.
Red Shales	400 to 500ft.
Penrith Sandstone	1,000ft.
	2,200 to 3,500ft.

The most northerly traces of magnesian limestone and plant-beds are seen in the banks of the Eden, near Lazonby.

At Cocklakes, about four miles S.E. of Carlisle, the shaly beds between the Penrith and St. Bees sandstones contain a thick bed of gypsum, which is quarried there. We are now, however, close to the northern boundary of the Penrith sandstone and the red shales overlying it, at least in Cumberland.

Two faults abut against each other at a spot in or close to the little river Petterill, a few yards above Newbiggin Bridge, which is a little more than three miles S.E. of Carlisle. One fault ranges eastward from this point to and beyond Brackenbank on the Eden. West of Newbiggin this fault probably crosses the Caldew, between Dalston Hall and the rifle butts at Cummersdale. The second fault ranges from Newbiggin, in a southwesterly direction, crossing the Caldew a little northward of Rose Castle. Both these faults

have a downthrow on their northern or north-western sides. The great lower Permian, or Penrith, sandstone is nowhere seen in Cumberland north of these lines from Brackenbank to Newbiggin, and thence to Rose Castle. Its most westerly appearance is in the Caldew, beneath Rose Castle bridge.

North of these lines of fault the only Permian or Triassic beds in Cumberland consist of the St. Bees sandstone and beds overlying it, including with the St. Bees sandstone a very thin breccia usually found at its base, such as may be seen in Shalk Beck.

If we now turn to the St. Bees district, we there find that the only Permian rock at all important, as regards thickness, is the great upper sandstone of the Eden Valley, which forms the headland of St. Bees. Sir R. Murchison and Professor Harkness have given the following details of Permian rocks at Barrowmouth, on the north side of St. Bees Head.* They rest on "purple sandstones of Carboniferous age," and consist of—

St. Bees Sandstone	(?1,000 feet or more)
Red Marls, with gypsum interstratified ...	30
Magnesian Limestone (thickening inland)...	11
Breccia	3

Thus nothing is to be seen at St. Bees to represent the Penrith sandstone of the Eden valley. Besides the certainty as to the true horizon of the St. Bees stone derived from the presence of the Magnesian Limestone beneath it, the two great sandstones, where they both exist, can be easily distinguished from each other. The Penrith stone is a lighter and brighter red than the St. Bees, and is also false-bedded to a very remarkable extent, while false-bedding is seldom, if ever, seen in the upper rock. And the finer grain and darker colour of the St. Bees stone make the two usually separable even in hand specimens.

Marine denudation has swept away the Permian rocks from the coast immediately north of St. Bees Head, but at Maryport they again reappear. The St. Bees sandstone is the only rock seen, and the boundary between it and the Carboniferous formation being a faulted one at Maryport, Aspatria, and S. of Wigton, the existence or not of magnesian limestone in those localities cannot be determined. We have already seen that there was none in Shalk

* "Quart. Jour. Geol. Soc.," 1864.

Beck. And in the Hether Burn, a little E. of Hethersgill, and in Carwinley Burn, a little above the bridge on the Penton and Longtown road, nothing is seen below the St. Bees sandstone, at the unconformable Carboniferous-Permian junction, but a thin breccia, like that in Shalk Beck. And I may remark that at both these junctions the contrast between the Permian brick-red and the Carboniferous purple-grey is as decided as in Shalk Beck.

The dip of the St. Bees sandstone varies usually from north to north-west between Maryport and the Caldew. It slowly changes between the Caldew and the Hether Burn (above Hetherbank Bridge) being about south-west at the latter place, West of the Esk the dip becomes more or less east of south, and at Annan it is nearly due north.

While the Permian rock, north of the Solway and east of the Annan Water, consists of St. Bees sandstone of ordinary appearance, the tract of country between Lochar Moss and the river Nith is composed of red sandstone precisely like that of Penrith. Thick beds of breccia occur in it. It is much quarried in the neighbourhood of the town of Dumfries. The relations between this Permian tract and that east of Annan do not appear, the ground between them being much covered by drift and peatmosses.

We may now cross the Solway from Annan to Abbey Town, the centre of the most sectionless part of Cumberland. Broad alluvial flats, low-lying peat mosses, and slightly more elevated tracts of glacial drift, are the only rocks visible. Two borings, however, one at Bowness, and the other a mile S. E. of Abbey Town, show that, below the drift, and above the St. Bees sandstone, lie 367 feet of Gypseous Shales at the former, and 700 feet at the latter place. And an old boring near Great Orton, made in search of coal in 1781, showed that below "different stone, mostly bluish" (or Liassic) were 132 feet of "red stone or clay sometimes mixed with veins of white." Now as the gypsum of the Bowness and Abbey Town borings was in thin laminae, this description of the rock below the Lias, near Great Orton, makes it highly probable—to say the least—that the Gypseous shales directly underlie the Lias there. In addition, "red stone or clay, sometimes mixed with veins of white," would not describe any other rock likely to be found in the district. And I may further remark that as the account of this Great Orton boring is derived from records which have been preserved for many generations by a most respectable

family long resident in the neighbourhood, there can be no doubt as to its trustworthiness.

In any case, this Great Orton boring offers the only evidence available as to the easterly extension of these Gypseous Shales. For at Tordoff Point, north of the Solway, is St. Bees sandstone; at Metalbridge on the Esk, and Rockcliff on the Eden, is a soft red false-bedded sandstone; while a recent boring at Justicetown, on the River Line (a little above its junction with the Esk) showed 170 feet of this soft red stone resting directly on that of St. Bees. The Gypseous Shales are equally invisible in the Caldew. Below Dalston Hall, above which point St. Bees sandstone appears here and there, the Brackenbank and Newbiggin fault probably crosses the Caldew, cutting off the Gypseous Shales—if they exist there—and bringing in the soft, red, false-bedded sandstone (just mentioned, as seen at Rockcliff and elsewhere) on its northern side. Thus the Gypseous Shales are nowhere visible at the surface.

I have called the rock next in succession—the soft, false-bedded sandstone just mentioned—the Kirklinton sandstone, because it is not only very well shown in the neighbourhood from which it derives its name, but its relations to both the underlying and overlying rocks may also be seen there. At Kirklinton, Westlinton, Netherby, Rockcliff, and Cummersdale it presents the appearance of a soft, false-bedded red sandstone. But wells at Carlisle, together with other evidence in its immediate neighbourhood, show the existence there, in the higher beds, of both red and white stone, while the highest beds, which appear in Skewbank, opposite Grinsdale, consist entirely of white or grey stone. The evidence as to the area occupied by this rock is as follows. A small section on the Petterill, a little above Petterill Bank, shows a soft red stone, apparently Kirklinton sandstone, and there is evidence of its existence in the record of the boring for the well at Garlands Lunatic Asylum. In the Eden it appears in the left bank, a little above Holmgate, and below the junction of Eden and Irthing. In the Hether Burn it may be seen in many places below Hether Bank bridge, above which are quarries in St. Bees sandstone. In the river Line the Kirklinton sandstone is seen to rest on the St. Bees, but the sections at the place of junction are somewhat obscure. In Carwinley Burn the junction is much clearer, and may be seen close to Carwinley Mill. There is some slight evidence of unconformity between the two rocks at the point of junction, but much

more decisive evidence may be seen on ascending the stream, till the junction of the Carboniferous and Permian rocks is reached. The sections in the St. Bees sandstone are almost continuous, and the rock, as in Shalk Beck, is flaggy and shaly towards the base. A thin breccia appears at the junction. But the total thickness of the St. Bees sandstone here can hardly exceed 250 feet. On the Hether Burn there may be about 800 feet of St. Bees sandstone between the outcrop of the Kirklinton sandstone and the Carboniferous-Permian junction. In neither of these cases are any faults seen, though in both there is an almost continuous series of sections. Thus in Carwinley Burn, not only have the Gypseous Shales (which overlie the St. Bees sandstone at Abbey Town and Bowness) disappeared, but the greater part of the St. Bees sandstone is also absent; the unconformity between the two sandstones being thus shown to be a very considerable one. The western boundary of the Kirklinton sandstone is a very doubtful one. Its most westerly exposures are in the lower part of Glinger Burn, in the Esk at Metalbridge, and in the Eden at Rockcliff. South of the Eden there are no sections, but it seems to me that the evidence of the old boring at Great Orton, already referred to, is quite sufficient to show that to map the Kirklinton sandstone so as to make it underlie the Lias west of that place would be to decide against the only evidence we possess, and would therefore be unjustifiable. White bands of rock exist in the Kirklinton sandstone, but "red stone *or clay* sometimes mixed with *veins* of white," applies only to the Gypseous Shales.

Two outliers of Kirklinton Sandstone have been pointed out to me. One, opposite Canobie Church, by the late J. Clifton Ward; the other on the Cambeck, west of Walton, by Mr E. J. Hebert.

The junction between the Kirklinton Sandstone and the overlying red and variegated marls and shales may be seen at Westlinton, a few yards E. of the bridge, and also in a little plantation on the edge of the alluvial flat, about midway between High Alstonby and Cliff Bridge, Kirklinton. The marls themselves may be seen here and there in the little streams that unite and fall into the Line between Low Alstonby and Westlinton, about as far eastward as Stonystonerigg. South of Stonystonerigg they are not visible till we reach the green at Houghton, where they appear on the bank of a pond. On their western border they are not seen between Westlinton on the Line, and the bank bounding the

alluvial flat of the Eden at Cargohill. They are well shown at the base of the left bank of the Eden at Beaumont, and are visible in the right bank, and bed of the river, S.S.W. of Cargo. The underlying Kirklinton sandstone is well shown, as regards its upper beds, at Skewbank. A fault a little E. of Skewbank brings in the Stanwix marls again on that side, and at the Spa Well, a few yards E. of this fault, and just at the bend of the river, the marls were found to be 23 feet thick, and to overlie white sandstone, which, in its turn, rested on red. (The exact place of this boring was only recently ascertained by Mr. R. Russell.) Above Grinsdale the marls may be seen at the base of the left bank as far as the North British railway bridge, and in the right bank at Etterby Scaur. I shall be obliged to dwell somewhat on the evidence as to the Stanwix Marls at Carlisle, as on this evidence it appears to me improbable that they underlie the Lias, except on its north-western border, their extension south of the Eden being very slight.

Nothing is known of them S. of the river about Beaumont or Grinsdale, and in the Eden their dip is usually slight and variable, the only high dips being at a spot a little north of Beaumont, on the one hand, and for a few yards west of the North British railway bridge, on the other. In the latter case they are probably the result of surface contortions, the underlying sandstone remaining perfectly level a little below the water-line.

At Rickerby, east of Rickerby House, Kirklinton Sandstone, with a north-westerly dip, appears in an old quarry in the bank bounding the alluvium, and fragments of the marls were seen in the left bank of the Eden a few yards north of the river end of Swift's Lane. I have seen traces of what seemed to me to be decomposed marls at the bottom of deep drains in front of Cavendish Place, in the Warwick road, in Lowther Street, and Bank Street, and at the foot of Gaol Brow. On the other hand their exceeding thinness at Carlisle is apparent from the fact that while these traces of the marls were only seen in the higher parts of the city, below 10 or 12 feet of drift, all the wells on the edges of the alluvium of the Eden or Caldew, together with all the railway bridges across the latter stream, are sunk through or based upon the underlying sandstone, their makers not having met with the marls at all. Again, there is no mention of marls having been seen in the well at the Gaol, which stands at a height of from 65 to 85 feet above the sea, or about that of the surface in the higher parts of Carlisle. But while the drift-covered surface in the

higher streets of Carlisle is only from 65 to 85 feet above ordnance datum, that of the alluvial flat of the Caldew, between the highest and lowest railway bridge, varies from 50 to 40 feet. West of the Caldew, at Messrs. Carr and Co.'s Works, on the edge of the alluvium, no marls were pierced in the well, which, below about 25 feet of gravel, was in red sandstone. And the late Mr. E. W. Binney states that "at the pumping engine for the canal by Edenside, immediately above the red and variegated marls, there was a section in the pump-well, which distinctly showed the marls at the top gradually passing down into the red sandstone below."* This pump-well was situated close to the North British railway bridge, at a spot where the marls form the base of the river cliff. Mr. R. B. Brockbank, the discoverer of the Lias in Cumberland, tells me that he used at one time often to bathe in the river in a long pool just below this spot. This pool was somewhat dangerous, as its sides were formed by ledges of rock ranging parallel with the line of the cliff, these ledges being from 1ft. 6in. to 2ft. in depth, and such as (Mr. Brockbank thinks) could hardly be made by the soft marls, and were, there can be little doubt, composed of the underlying sandstone. This is, indeed, what might be expected, considering the evidence of the pump-well, and also that the lowest Caldew railway bridge, about two-thirds of a mile due east, is based on the sandstone. Thus the evidence points to a marked change in the strike of the marls at Carlisle, from nearly N.N.E. and S.S.W. at Rickerby to E. and W. on and west of the Caldew. (See Section 2.)

The existence of Rhætic beds in this district is, and is likely to remain, an open question.† All fossils hitherto found in the Lias tract have been decided by Mr. Etheridge to belong to the Lower Lias. *Ammonites Johnstoni* has been found in both the lowest and highest beds, having apparently a vertical range of 200 feet or more. In the old boring near Great Orton, before mentioned, the thickness of the Lias was found to be 210 feet, and this is probably about the greatest thickness it attains. The Lias beds appear to consist of alternations of shale and limestone. The Lias area forms a plateau, the extent of which is more clearly seen west than

* "Lit. & Phil. Soc.," Manchester, ser. 3, vol. ii.

† I may remind any reader who may think the Stanwix Marls possibly Lower Rhætic (see Mr. Bristow's Section, "Geol. Mag.," 1864), of Mr. E. Wilson's paper, read at the Geol. Soc., June 21, 1882, showing that in the Nottinghamshire district there are often signs of erosion between the Avicula contorta beds and the Marls below.

east of Great Orton. In addition, all the known sections are in the district between Great Orton and Aikton. So far as I can judge from surface features, the Lias comes as near Carlisle as Bellvue, or a little nearer. And the words on the (6in.) map "Coalfell Hill," a few yards north of Bellevue, point also towards a probability that Lias exists there. For more than two centuries the Lias country has been the scene of borings for coal. Though situated in the midst of red rocks, coal measures exist but a few miles away, at Canobie on the north-east, and at Bolton Low Houses on the south-west. And the dark shales and blue limestones of the Lias are —apart from fossils—very like those of the Carboniferous rocks, and would naturally suggest to the local observer that in the Lias area the Carboniferous rocks again appeared at the surface. This view, indeed, is by no means utterly extinct at the present day.

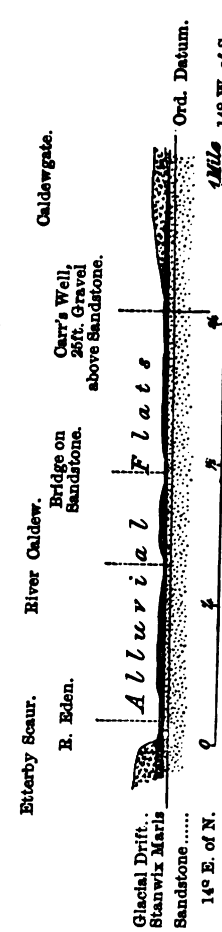


FIG 2. *Section to illustrate the necessary thinness of the Stanwix Marls in Caldewgate, W. of Carlisle, indicated by their absence beneath the Alluvial Flats. (Heights much exaggerated.)*

We have seen that the district now under review is, among other peculiarities, one of many unconformities. The basement Carboniferous Conglomerate rests unconformably on Lower and Upper Silurian rocks, while the Carboniferous Limestone rests unconformably on the conglomerate. And the unconformity between the Carboniferous and Permian systems is a very marked one. Then we have a decided unconformity of the Kirklinton sandstone to the St. Bees sandstone and Gypseous Shales; while the Stanwix Marls, in their turn, rest partly on the lower red and partly on the higher white beds of the Kirklinton sandstone. Lastly, so far as the evidence goes, it points towards the unconformity of the Lias to all the beds below. I have called the Kirklinton sandstone Bunter,

and the overlying Stanwix Marls Keuper, provisionally, to mark their unconformity to the beds below them and to each other. But a perusal of Mr. H. B. Woodward's paper upon the "Relations and Grouping of the Permian and Triassic Rocks"* shows the existence of so bewildering a variety of local conformities and unconformities among these beds, that I hold my classification of them but lightly, expecting that the rocks now called Permian and Triassic, united as they are by a common physical history, will shortly be classed under one common name.

As to the probable unconformity of the Lias to all the beds below, I will, in conclusion, remind you, in the first place, that the evidence of the old boring tended to show the existence of the Gypseous Shales directly below the Lias at Great Orton. Hence the restriction of the Kirklinton Sandstone below the Lias to the country east of Great Orton. And, secondly, the sudden change of strike in the Stanwix Marls at Carlisle from nearly north and south at Rickerby, to nearly east and west on the west side of Carlisle, together with their extreme thinness at and west of Carlisle, made it extremely unlikely that these marls existed below more than the north-eastern margin of the Lias. Of course this involves the mapping of the Lias as resting unconformably partly on the Gypseous Shales, and partly on the Kirklinton Sandstone and Stanwix Marls, and experience tells me that some geologists receive a shock on seeing this conclusion. But supposing my determination of these Stanwix Marls and Shales as Keuper to be much more questionable than I myself consider it to be, it must be evident that the Keuper is very poorly represented in this district, probably from the local erosion to which it has been subjected. And all that the unconformity of the Lias to the Stanwix Marls implies is some slight local erosion of the latter previous to the deposition of the Lias. In any case I think the duty of the Geological Surveyor is simply to map a district according to the evidence it presents; and that he is likely to weigh that evidence fairly in proportion as he can see it as it is, unprejudiced by any desire of making his work harmonize with what has been found in the same group of rocks elsewhere. And any manipulation of a map to over-ride the local evidence—conclusive or inconclusive—in order to produce a sham and short-lived harmony with other districts, I hold to be both dishonest and untenable.

* "Geol. Mag.," 1874.

EXCURSION TO THE WEST RIDING OF YORKSHIRE.

July 17th and Five Following Days.

Directors:—The President, and James W. Davis, Esq., F.G.S., F.L.S., Secretary of the Yorkshire Geological and Polytechnic Society.

(*Report by* The President.*)

The West Riding of Yorkshire exceeds in extent either Devonshire or Lincolnshire, yet in spite of its size the Carboniferous Rocks alone form a very large percentage of its area—a circumstance no doubt contributing largely to its wealth and importance. Thus, when people hear of the West Riding, visions of smoke and steam, of factories, collieries, forges and all the concomitants of a black country present themselves to the imagination. Yet the district visited on this occasion has none of these things, being purely agricultural or pastoral, mostly the latter; not densely inhabited, and constituting an agreeable tract of hill country which becomes mountainous towards the west. It forms part of a large block of older Carboniferous Rocks, which a series of east and west folds has brought to the surface between the Coal Fields of Durham and South Yorkshire, and is included within the wapontakes (hundreds) of Claro and Staincross, the latter being nearly coincident with the archdeaconry of Craven.

Claro commences where the first roots of the Pennine chain spring out of the Vale of York. Hydrographically it comprises the whole of the basin of the Nidd, together with small portions of the Ure on the north and of the Wharfe on the south. Harrogate, with nearly 10,000 inhabitants, is the largest town, but Knaresborough must be regarded as its historic capital. Excepting strips of Trias and Permian on the east, almost the whole of Claro is on Millstone Grit in parts covered by Drift. The surface ranges from 100 feet to 2,200 feet above sea level, and contains a considerable proportion of indifferent land, some of which, however, forms the best grouse ground in the county. There are wide upland plateaux with valleys of moderate slope: the hills never attain to the dignity of a peak, the most salient features being crags of gritstone, such as Almias Cliff (Kinder Grit), Brimham

* Some of the remarks made by the President at the previous meeting are incorporated with this report, especially in connection with the geology of Harrogate and Karesborough.

Rocks (Third Grit), and the rocking stones on Roggan Moor so celebrated in the annals of shooting. The Millstone Grits of this district contain waters of remarkable purity, and the valley of the Washburn is now the storehouse for Leeds, just as Loch Katrine is for Glasgow.

On reaching the valley of the Wharfe at Bolton a different kind of country begins to appear, though Bolton may be regarded as partaking of the Millstone Grit scenery of Claro, and of the Carboniferous Limestone scenery of Craven, where the hills are usually tabular, but with here and there a peaked termination. The weathering of the Carboniferous Limestone has produced long scaurs or cliffs, such as those at Malham, Gordale, and Kilnsea. The climate being wet and the soil calcareous, Craven is given over almost wholly to grass, and forms some of the very best and most feeding pasturage in England. Skipton is the principal town, and has always been regarded as its capital.*

* It used to be said that a squirrel could go from Knaresborough Castle to Skipton Castle without once touching the ground. Those were the days when Knaresborough Forest was covered with "*silva minuta*," most of which has long since disappeared.

Knaresborough was about as far south as the marauding Scots ever reached in their numerous forays into the north of England. During the disorganization which succeeded the battle of Bannockburn their army ravaged the country up to the very gates of York (A.D. 1319). The people of Ripon paid black-mail and were let off. The men of Knaresborough, a royal burgh, stood the risk of battle, and were defeated. Part of the inhabitants took to the church tower, where the Scots tried to burn them alive; the marks of the fire are said to be still visible. The Scots returned home by way of Skipton, which was also harried and burnt. The route between the two towns was so desolated that the Forest tenants were partly excused their rent to the King under the plea of impoverishment.

The more modern history of Knaresborough commences with the grant by Edward III. to John of Gaunt (A.D. 1371), since which time the town and district may be said to have followed the fortunes of the Duchy of Lancaster. About the same period Skipton was granted to Robert, Earl of Clifford, the ancestor of that ruthless partizan of the House of Lancaster, who slew the boy Earl of Rutland at the battle of Wakefield.

We cannot doubt that, during the wars of the Roses, the district between Knaresborough and Skipton must have been strongly Lancastrian; and thus it came to pass that, when Henry VI. and Queen Margaret lay at York in the spring of 1461, an order was issued, in the name of the King, to summon all "liege men of the forest and demesne of Knaresburgh" to join the Lancastrian army. This was a few days before that fatal Palm Sunday which witnessed the complete triumph of the Yorkists at Towton on the banks of the Cock,

> When the river ran all gory,
> And in hillocks lay the dead;
> And seven and thirty thousand
> Fell from the white and red,

—a battle wherein more Englishmen died than any other that has yet been fought. Sir William Plumpton, the commander of the Knaresborough con-

We obtain our knowledge of the geology of the country round Harrogate chiefly from Mr. Fox Strangway's "Memoir," whilst the excellent work of Davis and Lees treats of the West Riding as a whole.

The PERMIAN rocks in the eastern part of Claro, though mostly unfossiliferous, are not without interest. The *Lower Marl* has a very slight development; but 5 feet of red and grey marls, belonging to this section, are to be seen in St. Helen's Quarry, south-east of Knaresborough. These are the marls to which allusion will presently be made in connection with the subject of rock staining.

The most important member of the series is the *Magnesian Limestone*. But few fossils have been found in this district, and those chiefly from the lower beds, though traces of *Axinus* may be seen in beds which are highly dolomitized. At Knaresborough the yellow earthy variety is most frequent. It lends itself to the formation of caves, and, owing to its peculiar colour, imparts a character to the gorges through which nearly all the rivers of the West Riding have to pass on their way into the Vale of York. Most of these earthy varieties contain probably about 25 per cent. of carbonate of magnesia; they are quite useless as building stones, but make excellent mortar. This porous, spongy sort of rock passes into yellow crystalline dolomite, frequently showing coloured bands; the more ferriferous varieties being studded with radiations of a metallic oxide, which is probably magnetite.* No purer form of dolomite than this would seem to occur in the Knaresborough district. But a few miles further south the crystalline dolomites of Huddleston Quarry are famous; there occurs also in Towton Field a form of Magnesian Limestone which is concretionary in small ovoids, almost resembling an oolite.

The *Middle Marl* succeeds the Magnesian Limestone, and in some cases must overlap it. This sub-division consists of red marls, and soft red sandstone with much gypsum. Above it some

tingent, was taken prisoner, and his son slain along with many others of less degree, so that days of mourning fell upon the manor and forest.

The bloody Lord of Skipton, Shakespeare notwithstanding, had fallen in a preliminary skirmish, but his youthful son, afterwards known as the Shepherd Earl, found refuge under the care of Sir Launcelot Threlkeld in the wilds of Saddleback, whence he emerged to resume his rank and estates on the final triumph of the House of Lancaster.

The part played by the Royalist castles of Knaresborough and Skipton, during the Parliamentary wars, is too well known to require further mention.

* These markings, on examination, are seen not to be dendritic; they may, nevertheless, contain some oxide of manganese.

small remains of the *Upper Limestone* are visible in a cutting to the west of Knaresborough.

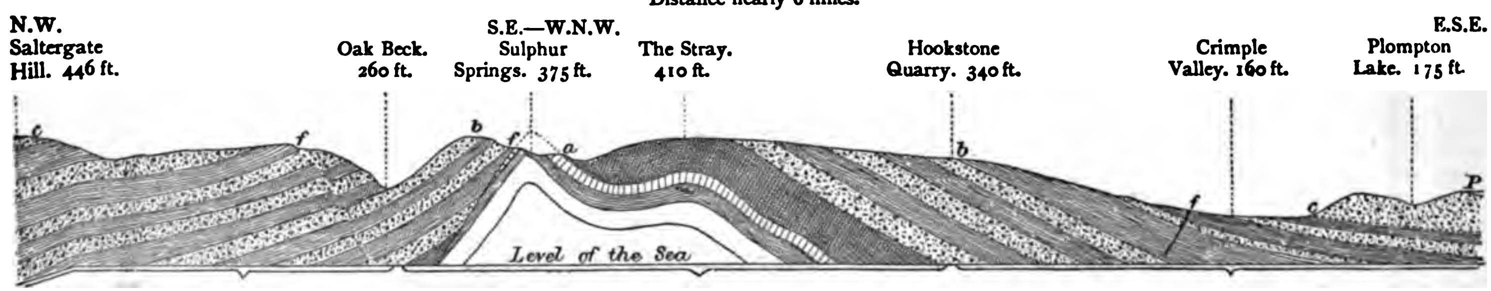
The association of gypseous marls with beds of magnesian limestone is worthy of attention as having an important bearing on the origin of magnesian limestones generally, regarding which there are so many rival theories. Is the double carbonate a contemporaneous product, or the result of subsequent dolomitization? Some are disposed to regard the formation of magnesian limestone as the result of precipitation in an inland sea, or at any rate of deposits due to streams charged with carbonate of lime and sulphate of magnesia, when, as Sterry Hunt has endeavoured to show, dolomite and gypsum would be the products. Prof. Green thinks that the palæontological facts noted in the Magnesian Limestone of Yorkshire favour this view, and he gives a history of the sequence of events, beginning with sandy deposits (the quicksands at the base of the Permian in South Yorkshire), which pass into sandy dolomites, and thence into pure dolomite. The fossils occur mostly in the lower beds, and, as the waters became more highly charged with saline matters, so life became scanty and dwarfed. He also looked to volcanic action as a source of supply for magnesian salts; but Mr. Lucas pointed out that the requisite materials might have been derived from the Yoredale Rocks and Millstone Grit of the neighbourhood, which were in all probability already above water. These questions have an additional interest as bearing on the probable position of the old shore line of the Permian Sea in these parts, and on the date of the Pennine upheaval.

The MILLSTONE GRIT Series is classified by Davis and Lees under the head of shore deposits with marine intercalations. The name serves to show the misleading character of a petrological title, as the group is full of shales, often with much ironstone, the smelting of which in former years had much to do with the disappearance of wood from Knaresborough Forest.

In the neighbourhood of Harrogate and Knaresborough the upper divisions of the Millstone Grit, including the "*Rough Rock*," are wanting, the highest beds now found belonging to the "*Third grits*." This circumstance is of course the result of pre-Permian denudation, which has not only removed the Coal Measures, but a considerable portion of the Millstone Grit likewise. Consequently, in this district, the Permians repose unconformably upon certain quartzo-felspathic grits, which are often of a red or purple colour. These are largely developed throughout many parts of the

DIAGRAMMATIC SECTION THROUGH THE HARROGATE ANTICLINAL.

Distance nearly 6 miles.



Millstone Grit Series on the North Side of the Anticlinal. Anticlinal of Yoredale Rocks. Millstone Grit Series on the South Side of the Anticlinal.

Explanation of Signs.—*a.* Harrogate roadstone. On the north side of the anticlinal this is forced against the principal fault (*f*). *b.* The Uppermost Kinder Grit. Quarried on the south side of the anticlinal at Hookstone; on the north side of the anticlinal forms Birk Crag. *c.* Approximate position of the fossiliferous band (Cayton Gill Beds) in the Millstone Grit on either side of the anticlinal. *P.* Permian Beds (here Magnesian Limestone) resting unconformably on the Plompton Grits.

The Yoredale Rocks are here composed of—*Lower Grits, Lower Shale, Calciferous Encrinital Grit* (Harrogate roadstone, *a*), *Upper Shale.*

Millstone Grit.—The three lowest Grit Beds with their accompanying Shales are called the *Fourth*, or *Kinder Grits.* A thick Shale intervenes. The upper series of Grits and Shales are referred to the *Third Grits.*

This section may be regarded as approximately correct as far as the surface is concerned. The folding of the Yoredale Rocks beneath the Stray is, to a certain extent, hypothetical. When the railway was made across the Stray the beds were observed to be so much disturbed that it was thought by some that the principal axis of elevation was at this point, rather than at the Sulphur Springs.

The Millstone Grit series consist very largely of Shale. It must not be supposed that the relative thickness of the Grits and Shales is accurately delineated in the diagram. Even the Plompton Grits, which form the highest section of the Third Grits in this district, are by no means free from associated Shales.

drainage area of the river Nidd, appearing in moderate elevations at Plompton, but rising to a height of nearly 1,000 feet above sea level in Brimham Rocks.

It is these Plompton grits which the older geologists were disposed to regard as the equivalent of the "Rothliegende," apparently from a general impression that the base of the Permian should be *red*, in order to correspond with the beds in Germany. The Red Rock of Rotherham, now known to be a member of the Upper Coal Measures, was for a long time classed with the "Rothliegende," in deference probably to the opinions of Phillips and Sedgwick. It is hardly necessary to repeat that, throughout Yorkshire, the unconformity of the true Permian to all members of the Carboniferous is one of the most marked features in the stratigraphy of the country. This was recognized by Phillips, and yet he persisted in regarding the Plompton Grits as "Rothliegende." Mr. Binney seems to have been the first to suspect, from the character of the few fossil plants occasionally found in these beds, that they were not of Permian age, whilst later on Mr. Clifton Ward and the Government Surveyors succeeded in establishing their true stratigraphical position as members of the Millstone Grit.

The coloration of these beds has also been the subject of much controversy. The causes which have produced rock-staining in the lower beds at the junction of the Permian and Carboniferous in these parts may not be all of the same nature. Mr. Ward thought that the prevalence of a red colour in the underlying rock might be due to some action exerted by the Magnesian Limestone on the percolations; and this notion has attained a certain degree of acceptance, though it is difficult on chemical grounds to see exactly what the nature of such action can be. Moreover it is quite an open question whether there really is any increase of red colour in the grits which lie beneath the Magnesian Limestone; indeed, that there is any such increase is denied by Mr. Lucas, who, as before mentioned, was inclined to attribute some of the red colouring to a lower marl now removed. In many parts of the Nidd valley the stratum of grit in actual junction with the Magnesian Limestone is often less highly coloured than the bed below. There can be very little doubt that much of the red colour of the Plompton Grits is due to the quantity of red felspar which they contain, so that possibly the principal causes were pre-existent within the rock itself.

The fossiliferous horizon known as the Cayton Gill Beds (*c* of the diagram, Fig. 1) is seen on both sides of the Harrogate anticlinal. *Productus semireticulatus* is the most abundant fossil; *Streptorhynchus crenistria* is fairly plentiful, as also a very pretty *Fenestella;* the joints of Encrinites are very abundant.

Kinder-Grits.—The base of the Millstone Grit consists of three thick grit beds associated with still thicker shales. Some of these grits have been extensively used for building stone at Harrogate, but they are very porous. Though usually pretty free from strong colours, some of these beds are very purple in places, though exposure soon removes the tint. The outliers of the Millstone Grit Series in Craven mostly belong to this section.

YOREDALE ROCKS.—This is a group established by Phillips for a variable series of beds between the Carboniferous or Scar Limestone of Craven, and the Millstone Grit. It is well developed in Craven and throughout the west, consisting of shales, limestones, and peculiar grits, often calciferous. In the bed of the Hodder Yoredale Shales, with their limestones and layers of ironstone, give rise to springs containing sulphuretted hydrogen. In Bowland Forest these shales are dark and full of molluscan and fish remains. Near Skipton the Yoredale rocks consist of calcareous shales and limestones with many fossils, the beds sometimes being of a ferruginous and bituminous character; sulphur springs occur here in a position somewhat analogous to those at Harrogate. The attitude of the Yoredale Rocks at the latter place may be gathered from the diagram, Fig. 1. Very little is known about the shales of this group, but the Harrogate roadstone (*a* of the diagram) is a remarkable rock; below this are other shales and another peculiar grit.

The Yoredale grits at Harrogate are so peculiar that, being in some way connected also with the phenomena of the sulphur springs, a brief description may be useful before proceeding to consider the subject of the waters themselves. A large hand specimen from the Beckwithshaw quarry shows three different phases. Firstly, a fine-grained quartzo-felspathic grit without lime; secondly, a calciferous encrinite-grit, where the lime has mostly been removed, but where the structure of the crinoidal stem is better brought out in consequence; thirdly, a more calcareous portion. A hand specimen from the bottom of the sulphur well on Harlow Carr is a very fine-grained quartzo-felspathic grit with much white mica, and coaly matter in bands and blotches. In the Low Harrogate quarry (Cold Bath

HARROGATE WATERS.—ANALYSES.

No. 1.—Old Sulphur Well (Strong saline Sulphur). Thorpe, 1875.

	Grains in Gall.		Grains in Gall.
Sodium Chloride	893·7	Total haloids ...	... 1005·5
KCl 9·6, LiCl 0·7, NH_4Cl 1, $CaCl_2$ 43·5, $BaCl_2$ 6·6, $MgCl_2$ 48 ...	109·4		
Magnesium Iodide	0·1		
„ Bromide	2·3		
Calcium carbonate	29·8	Total earthy carbonates	35·8
Magnesium carbonate	6·0		
Alkaline carbonates		... ...	nil.
Sulphates		... ...	nil.
Silica		... ...	0·7
Sodium Sulphydrate (NaHS)		... ...	5·2
F, Sr, P_2O_5, Al_2O_3, and organic matter		... ...	traces
Total solids		... ...	1047.2

GASES.

Note.—The amount of free H_2S found by Thorpe dissolved in the water = 3·7 grains per gallon. In his paper in the "Journal of the Chemical Society" no other gases are mentioned. Hofmann in 1854 found carbonic acid 22 cubic inches, carburetted hydrogen 6 cubic inches, nitrogen 3 cubic inches. He also states that the bubbles rising from these waters spontaneously consist mainly of carburetted hydrogen and nitrogen.

Temperature.—In 1872 this was found to range between 46°F. and 52°F.

No. 2.—"Magnesia" Well (Mild saline Sulphur). Muspratt, 1867.

Hospital Mild Sulphur.

	Grains in Gall.	Grains in Gall.
Sodium chloride	[illegible]	tr.
Silica	... ...	tr.
Organic matter	... ...	
Total solids	... ...	10·0

Gases.—Principally carbonic acid, with some nitrogen, and traces of carburetted hydrogen and of oxygen.

oad) the crinoidal character is very prevalent, and where the soluble matter has been removed, it becomes a spongy, silicious, encrinite grit. The decomposition of this rock produces a good soil, but we may well believe that the surface beds have already parted with some of their constituents, and the iron-stained nature of the joint faces points in the same direction; it is in the stuff formed in these cracks that the little double-pyramid quartz crystals, known as Harrogate diamonds, have been deposited.

The Harrogate waters,* both sulphur and iron, occur in connection with a triangular patch of Yoredale rocks, of which a cross section is seen in Fig. 1. This patch is bounded towards the N.W. by the main fault, and extends for about three miles S.W. of Harrogate. There are about 80 springs in all. The strongest waters rise in the little valley of Low Harrogate between the Bog Field, 375 feet, to the Montpelier Spa, 335 feet. This is the nucleus of the sulphur waters; the strong iron waters are near, but usually occupy an outer area. It is evident that an iron water and a sulphur water are incompatible, yet they wait closely on each other, and must in some way be connected. One of the great puzzles is to understand how they are kept apart in the ducts which convey them to the surface. The very high angle of the beds, and the peculiar jointing of the encrinite grit have probably something to do with it.

The composition of the Harrogate waters has often been studied from a therapeutical point of view, but it has also its geological aspect, and recent observations have brought out some features of considerable importance in this direction. Henceforth there will be less difficulty in understanding the vein deposits of the Carboniferous Series, as here we have an opportunity of testing the vital fluids of the rocks, as it were, in the act of circulation. An inspection of the accompanying table may serve to illustrate this.

The five waters, whose analyses are there given, are representative of the chief varieties. Technically the *Sulphur waters* are divided into strong saline, mild saline, and pure, the latter term being merely relative. It may also be noted that No. 3, selected as a type of the "pure sulphur," is situated at some distance from the triangular patch of Yoredale Rocks previously mentioned, and very near the junction of the Millstone Grit Shales with the Middle Permian Marls. At the same time it is not improbable

* For further details consult "The Harrogate Waters," by George Oliver, M.D.—H. K. Lewis, London.

that this spring may represent an overflow from a spring at Bilton, which is more in the direction of a slight prolongation of the anticlinal axis. In consequence of the absence from this water of the chlorides of the alkaline earths, there is a fair amount of alkaline carbonate, and the same is the case with the spring at Harlow Carr on the other side of Low Harrogate. In fact the further away from Low Harrogate the less amount of chloride occurs in the sulphur springs.

The Old Sulphur Well yields a pretty uniform supply, amounting to about 12 gallons per hour, though in the very dry year, 1868, there was some mention made of a threatened deficiency. The temperature is evidently pretty nearly that of the air, so that no appreciable amount of extraneous heat can be detected. Indeed it may be said that all the waters of Harrogate are "cold," and, with one exception (the Alum Well), they all have a markedly alkaline reaction. Calculating roughly, the Old Sulphur Well would yield seven tons of chlorides per annum, including 100lbs. of Barium Choride,* and 37lbs. of Magnesium Bromide, with some Iodide. It also would produce 240lbs. of Sodium Sulphydrate (NaHS).

The origin or source of these abundant impregnations has naturally been a matter of considerable difficulty. The most probable explanation is that the springs, though not superficial, are far from being deep-seated, and that the water supply comes mostly from the Harlow Hill district, which attains 600ft. elevation, and attracts a rainfall that cannot well average less than 35 inches annually. That the supply is not superficial may be inferred from the fact that the drainage of the Bog Field had no effect on the delivery of the waters, and thus the notion, held by Phillips, as to the bog origin of the sulphur waters would seem to be untenable. The large quantity of chlorides looks very much as if a portion of the water of the sea or of an estuary† had been

* Barium Chloride was not noticed by Hoffman in 1854, and that chemist only found traces of Bromides and Iodides. Improvements in methods of analysis may account for the difference.

† Comparing the total solids of the Mediterranean with those of the Baltic, the following differences may be noted:—

	Mediterranean.	Baltic.
Solids in 100	3·77	1·77
Haloids per cent.	89·5	94·5
Sulphates	10·2	5·2
Carbonates	0·5	0·3
	100	100

See "Bischof.," vol. i., pp. 105 and 107.

evaporated and the salts incorporated with the Yoredale Rocks during their formation. There is abundant evidence, both in this neighbourhood and elsewhere, of the quantity of organic matter, chiefly of vegetable origin, locked up in the Yoredale Rocks. Hence it is not unreasonable to believe that the putrefactive distillation of such organic matter, acting very slowly and through long periods of time, more or less effects the complete deoxidization of the sulphates, and that to this we owe the quantity of sulphide present in the Harrogate waters. The considerable quantity of carburetted hydrogen and of nitrogen found by Hoffman all favour this view, which is much strengthened by the almost complete absence of oxygen, showing that the nitrogen present is due to organic decomposition. At the same time the very slight traces of phosphoric acid would show that this mainly arises from vegetable matter.

EXCURSION.

Monday.—The London contingent arrived at Harrogate early in the afternoon, and having secured quarters at the Prospect Hotel, re-assembled with the other members of the party at the Old Sulphur Well. Here they tested the quality of the water for which the place is celebrated, and availed themselves of the permission which was given to them to descend underneath the floor of the building to inspect the springs which supply the pump-room above. The President, who on this occasion was the director, offered a few remarks on the chemical composition of the water and of several of the sulphur waters of Harrogate. He was enabled to illustrate his observations by means of a number of specimen tubes containing the saline contents of one gallon of each of the various waters to be found in the town, and by this method the different volumes were at once perceived. These very interesting tubes had been prepared from evaporations conducted by Mr. Davis, chemist, of Harrogate. They are the property of the Harrogate Improvement Commissioners, who kindly lent them for the occasion. Mr. W. H. Wyles (the Clerk to the Commissioners), and Mr. W. W. Harry (the engineer) afforded the party every facility in the examination of the specimens. Whilst the company were thus engaged, Dr. Oliver, who is well known as the author of a valuable work on "The Harrogate Waters," appeared at the wells and supplemented the President's observations. Dr. Oliver dwelt more especially upon the geological conditions under which the water finds its way

to the surface in connection with the very remarkable anticlinal which is known to exist at Low Harrogate.

The singular stratigraphy of Harrogate arrested the attention of geologists a long time ago. Mr. Wm. Smith, the father of English geology, was the first to appreciate the peculiarity, but although he recognised that there was an anticlinal or upthrust of lower rocks, extending from Harlow Hill to Low Harrogate, he appears to have thought that within that anticlinal there was a synclinal basin towards which the springs gravitated. Later on, his nephew, the late Professor Phillips, who for forty years had given great consideration to the peculiarities of the geology of Harrogate, drew the attention of the Geological Society of London to the very remarkable features of the district, the difficulties in regard to which had been to some extent cleared up by the making of the new railway across the Stray. The subject of the anticlinal was treated generally in a diagram in the paper brought before the Geological Society by Professor Phillips, and the relation of the Millstone Grit beds on the north and south of the Yoredale rocks beneath was made very clear. At the same time Professor Phillips seems to have had a notion that there was a sort of synclinal towards the apex of the anticlinal, and his section at this part of the diagram is somewhat obscure and difficult to comprehend.

When the party left the Old Sulphur Wells they proceeded to verify the stratigraphical facts in connection with the anticlinal, and for this purpose walked to the well-known road-stone quarry in the Cold Bath Road. This stone is one of the hard beds of the Yoredale rocks, and may be described as a calciferous grit very largely charged with the remains of encrinites. In the Cold Bath Road quarry these rocks are to be seen dipping at a considerable angle in a south-easterly direction. In the bed of the stream, just at the back of the sulphur well, the same rock is observed to dip in a direction somewhat to the north of east, and a little further up the hill, underneath Cornwall House, this same bed dips at a very high angle indeed, nearly due north. These facts are taken to indicate that there exists an anticlinal dome, which is here seen to be dying out to the eastward, and the north side of the anticlinal is very much steeper than the south—in fact, the anticlinal itself is fractured a little on the north-west side of what may be presumed to be its principal axis by a great fault which causes the road-stone to be brought into juxtaposition with the lower beds of the Mill-

stone Grit. There are geologists at Harrogate who consider that the axis of this swelling or anticlinal is to be found beneath the Stray rather than at the sulphur springs, and this view receives some substantiation from the appearances which were noted when the railway was made across the Stray. The probable explanation is that the Harrogate road-stone and its accompanying shales are bent into more than one series of curves, and that one of these curves very nearly reaches the surface in the railway cutting. A northerly dip of the beds near the Low Harrogate Church is further evidence of the probability of this view.

The party having satisfied themselves as to the reality of the anticlinal axis, were conducted to the Bog Springs, where there are something like 34 different sources of sulphur and iron waters. Dr. Oliver here indicated the peculiarities of the position and the nature of the several waters, and deduced from his observations the fact that, as a rule, the sulphur springs occupy an inner position, and that the iron springs are without, on either side of the main axis of upheaval. The nature of the several wells was pointed out, and attention was especially drawn to the very abnormal water known as the "Alum Well." It may be mentioned that one of the characteristics of the sulphur waters at Harrogate is the absence, more or less complete, of sulphates. This peculiarity enables many of the Harrogate waters to act as carriers of salts of barium and strontium, which would otherwise be insoluble. In the "Alum Well," however, a large quantity of sulphates exists. The probability is that this is due to the shallow origin of the spring, whose waters become oxidised, and this may account also for the acid reaction so exceptional to the waters of this neighbourhood.

Having spent some time at the springs, the company walked to Birk Crag, where they had an opportunity of looking from that very picturesque ridge of Millstone Grit over the wild and dreary scenery of Haverah Park, which consists entirely of the grits and shales of the Millstone Grit group. These rocks are noted for the purity of their waters. Oak Beck, which flows through Haverah Park, has been utilized for the purpose of supplying the town of Harrogate with pure water, just as the Washburn river has been adapted for supplying Leeds. The remainder of the evening was spent by the party in walking round by Harlow Carr and the back of Harlow Hill to Harrogate. They afterwards met at the Prospect Hotel, and were very kindly welcomed to Harrogate by Mr. Richard Carter, F.G.S., of Spring Bank, Harrogate, who, with Mr. Harry

and other gentlemen, had done much to facilitate the success of the excursion.

Tuesday.—The party left Harrogate for Knaresborough by an early train, and after a brief inspection of the old castle at the latter place, descended to the foot of the cliff on which what is left of the ancient pile stands. Here the unconformable junction of the Magnesian Limestone upon the Millstone Grit was pointed out by the Director (the President of the Association) and verified by the members. From this point the party crossed the river for the purpose of visiting the Dropping Well, which is too well-known to need describing here. The Director took occasion to explain the nature of the waters which flow over the rock. The stream supplying these waters springs out of the adjacent cliff, and represents the drainage of a hollow originating in the high ground towards Belmont. This ground is chiefly made up of the Middle Permian Marls, and it is to the salts in these marls that we must trace the impregnation of the Dropping Well waters. The following is an old analysis of the water :—

	Grains to the Gallon.
Carbonate of Soda ...	... 6
Carbonate of Lime ...	... 23
Sulphate of Lime ...	... 132
Sulphate of Magnesia ...	... 11
Total	... 172

The deposits upon the sponges and other substances which are placed at the well, consist almost wholly of carbonate of lime, the amount of sulphate of lime deposited being very small indeed, notwithstanding the very large quantity of sulphate of lime found in the water. Mr. Simpson, the lessee of the Long Walk and the Mother Shipton Inn, recently possessed himself of some magnificent specimens of sponges, which show the action of the deposit remarkably well from their porous nature. Some time was spent by the party in examining the various caves in the valley of the Nidd, and in listening to stories about St. Robert and Eugene Aram, after which they crossed the river at Grimbald Bridge, and finally took leave of the Magnesian Limestone where the romantic Grimbald Crag is terminated by a small fault on its western side. Plompton Rocks—a mile and a half distant—were very soon reached. These rocks are interesting to geologists from having

been regarded in former days as constituting a portion of the Permian series—equivalent to the German "Rothliegende." The researches of the Government surveyors in recent years have shown that these rocks are really nothing more than the highest beds of the Millstone Grit series, as developed in this district, and that they are unconformably overlaid, just as at Knaresborough, by the Permian rocks. The extraordinary action of the weather upon these curious grits afforded matter for endless speculation. In this respect the Plompton Rocks, which belong to the same bed of grit which forms the Brimham Rocks at a much greater elevation, are possibly more singular and grotesque than even the Brimham rocks themselves.

The party now divided, some returning to Harrogate in carriages, others walking along the road. In the afternoon they were joined by Mr. J. W. Davis, when about a dozen of the most enthusiastic members, including that gentleman and the President drove to inspect the new quarry of Harrogate road-stone at Beckwithshaw, where the effects of contortion are very finely displayed. A small spring of sulphur water has recently been discovered near here by Dr. Oliver. In the evening the President congratulated the members on the arrival of Mr. Davis, and placed the direction of the excusions for the remainder of the week in his hands.

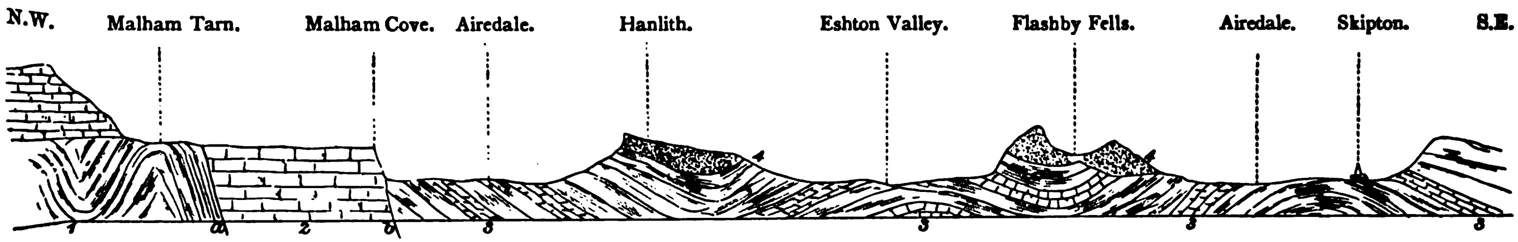
Wednesday.—This was an important day for the excursionists as they had to transfer themselves in conveyances from the base of operations at Harrogate to Skipton, *viâ* Knaresborough Forest and Bolton. The early part of the journey was sufficiently dreary, the scenery of this portion of Knaresborough Forest being somewhat tame and uninteresting. A number of fossils were discovered on the stoneheaps near the Little Wonder Inn, coming from the well-known quarries in the Millstone Grit series near Hampsthwaite, on the horizon known as the "Cayton Gill Beds" (see diagram No. 1). The excessive rarity of fossils in the Millstone Grit makes their occurrence in this bed of considerable interest. The species appear to differ but slightly from such as are known to occur in the Carboniferous Limestone. Having safely passed the "dangerous corner" the Director and his followers descended into the valley of the Washburn, where the extraordinary size of the artificial lakes provided for the Leeds water-supply, struck everyone with astonishment. The Pass of Kexgill, the next object of interest on the route, shows traces of the anticlinal axis by the

way in which the grit rocks dip on either side. Having reached the summit of this pass the party drove rapidly down the descent to Bolton Bridge, and at about half-past twelve arrived at the Devonshire Arms, where a substantial lunch, for which the excursionists were well prepared, was served. About four hours were devoted to Bolton Abbey and the Strid, where many of the gentlemen from the south saw for the first time one of the most beautiful and interesting spots in Yorkshire; indeed, so fascinated were they with the charms of this delightful valley, that it was rather late when the journey was resumed. It may be stated that the Strid is cut through what is known as the Kinderscout grit, or lowest grit of the Millstone Grit series. Opposite Bolton Abbey there is a very fine section in the Yoredale shales, showing both faults and contortions. This is on the north side of the anticlinal. The stratigraphical phenomena between Bolton and Skipton are of the most marvellous kind. (See diagram, fig. 2, S.E. side, for the general structure of the Skipton Anticlinal). The long system of disturbance extending from the neighbourhood of Clitheroe to Harrogate, here assumes a most striking phase, and the quarries in consequence exhibit some extraordinary sections. The first quarries visited are known as the Hambleton Rock Quarries, where the Skipton rock, supposed to be Mountain Limestone, has been forced into a vertical position, and is variously contorted. Continuing the drive towards Skipton, the party made a diversion in the direction of Draughton Quarry, an excavation in the Yoredale rocks, where the most remarkable phenomena of rock-curvature may be seen to great advantage. Some of the choicest of these have been photographed by the Yorkshire Geological Society, and form beautiful pictures apart from their supreme geological interest. The excursionists had considerable difficulty in finding their carriages again. Skipton was not reached until a late hour in the evening, and it was some time before the party was settled in their various quarters; but, thanks to the admirable arrangements made by Mr. Davis, everything was finally put to rights.

Thursday.—This morning the party, accompanied by a few members of the Yorkshire Geological Society, travelled from Skipton to Bell Busk, and most of them walked from that Station to the village of Malham, a distance of nearly five miles. The hillocky character of the intervening country is chiefly due to the prevalence of glacial deposits. Malham Cove is situated not far from the south branch of the Craven fault. (See diagram, fig. 2, N.W.

FIG. 2.

DIAGRAMMATIC SECTION FROM MALHAM TO SKIPTON. Distance 12 miles.



Explanation of Signs.—1. SILURIAN GRITS. 2. MOUNTAIN LIMESTONE. 3. YOREDALE SERIES. 4. MILLSTONE GRIT. *a.* North branch of Craven Fault; *b.* South branch.

This section is designed to give an approximate idea of the position and contorted character of the rocks in the vicinity of the Craven Fault, and for many miles southward. The surface of the valleys is for the most part thickly covered with glacial clays, sand and boulders; but where exposures of the rock are met with they always exhibit a more or less contorted section. At Malham Tarn the Mountain Limestone extends in more or less horizontal beds on the upturned edges of the Silurian rocks. The grit rocks which occupy the higher ground at Hanlith and Flashby Fells are in the form of synclinals, whilst the summits of the anticlinals occupy the lower parts of the valleys. At Skipton a Limestone is quarried, which is supposed to be equivalent to the Mountain Limestone at Malham, but this is by no means certain.

side). The Director having arrived at the foot of that remarkable cliff, just where the river Aire springs from the base of the precipice, drew attention to the geological characteristics of the scene, more especially in connection with the underground course of the water which disappears a little to the south of Malham Tarn. The party retraced their steps in the direction of the village of Malham, and thence walked towards Gordale Scar, some of the gentlemen visiting Janet's Cave on the way. The gorge at Gordale is an excavation in what is known as the Scar Limestone, which is the lowest member of the Carboniferous Series in this district. The visitors were scarcely prepared for such an impressive scene, and nearly all agreed that it is one of the most remarkable spots, not only in Yorkshire but in England, and that probably no part of the Carboniferous Limestone, not even excepting the celebrated Cheddar Cliffs, can compete with Gordale in wonder and magnificence. The stream which flows through this extraordinary cañon, by its numerous waterfalls, adds largely to the interest of the scene. There can be very little doubt that this excavation is almost entirely the result of water action, aided to a certain extent by rock-jointing in the first instance. The scramble up the gorge is a somewhat difficult undertaking, but was safely accomplished, and the whole of the party finally stood on the limestone pavement of the moors above. From thence a rather rough walk led them to within a short distance of Malham Tarn, which is said to be situated on Silurian rocks and Boulder Clay.

At the place where the water sinks, to reappear, as already stated, at the foot of Malham Cove, Mr. Davis read a very interesting communication from Mr. Walter Morrison with reference to the underground course of the water, which disappears at this point. The Director expressed his opinion that the water at once falls into the north branch of the Craven fault, which crosses the moors about this spot. The kindness of Mr. Morrison in offering the party the use of boats and other facilities was duly acknowledged by the President, and Mr. Davis was requested to convey the thanks of the Association to that gentleman. Here the party divided. A number of them returned at once towards Malham, and thence to Bell Busk, whilst the other portion, under the guidance of Mr. Davis, took the road across the moors for the Victoria Cave and Settle. Owing to the inequalities of the ground, the latter party became subdivided, though both sections arrived at the Victoria Cave about the same time. Certain observations relative

to the position of the great north fault were made by some of the gentlemen present. This party finally descended into Settle by a very precipitous route. After a hurried visit to the museum at Giggleswick, where many of the objects found in the Victoria Cave are arranged, including the largest specimen of the grizzly bear which was ever found, the excursionists got to Settle Station just in time to catch the train for Skipton.

Friday.—The weather, which had hitherto favoured the excursionists in a most remarkable manner, changed for the first time during the week on Friday morning, when in a heavy shower the party proceeded from Skipton to Clapham. On the arrival of the party at the latter place the clouds broke, and it was comparatively fine for a few hours. This enabled Mr. Davis to take his trusty followers through the grounds belonging to Mr. Farrer, where the effects of one of the great faults are very well shown in the gorge of the stream. A section of the party then visited the celebrated Clapham Caves, whilst a smaller number proceeded up Trout Gill to Gaping Ghyll Hole. It is very well known that the waters which are collected on the southern flanks of Ingleborough, and which flow as an ordinary beck up to this point, suddenly disappear in the yawning limestone, just as one might imagine a river turned into a pit shaft. The waters are doubtless those which reappear close to the Clapham Cave. At some time or other the course of this stream was on the surface, and the lines of the old valley are still to be seen, though the stream no longer excavates that portion of the valley between Gaping Ghyll Hole and the place of its final emergence into daylight at the Clapham Caves. It may be as well here to draw attention to the readiness with which water sinks in these limestone districts—a circumstance due partly to the jointing of the rocks themselves and partly to their ready solubility in carbonated waters.

Both branches of the party ultimately returned to Clapham, where they re-assembled at lunch, which was liberally provided by the landlord of the New Inn. Before leaving the table the President took the opportunity of tendering the thanks of the Association to Mr. Davis for the admirable manner in which he had conducted the excursions. He spoke of that gentleman's extensive knowledge of the geological features of the district, and referred to the trouble which he had taken in making the arrangements which had given so much satisfaction to the visitors. Mr. Davis made a suitable reply, in the course of which he expressed his gratification

at having made the acquaintance of so many gentlemen, whom he facetiously described as the jolliest set of geologists he had ever met with.

The rain was now coming down in torrents, and under these depressing circumstances very few of the members or their friends showed any anxiety to carry out the programme to its final completion. Only ten were found bold enough to enter upon the undertaking, including the President and the Director. These gentlemen, well armed with umbrellas and waterproofs, walked, in a pouring rain which did not cease for a moment, first of all to Norber—a distance of over a mile—where they saw the magnificent display of ice-borne boulders of Silurian rocks resting on Mountain Limestone. By the hamlet of Wharfe the small party walked round Moughten Fells to Foredale. At Combe Quarries they had to be satisfied with a glimpse at the section, rendered classical by the splendid photograph of the Yorkshire Geological Society, where the Mountain Limestone lies unconformably on the upturned and folded edges of the Silurian slates and grits. A hurried walk took them to Horton-in-Ribblesdale, where they had the good fortune to catch the 6.43 train to Skipton.

Saturday.—The contemplated excursion to Raygill Quarries was abandoned, partly in consequence of the threatening nature of the weather and partly because many of the members were anxious to return to their homes in good time. It may be mentioned that at Raygill Quarries there is a fissure recently excavated by the Yorkshire Geological and Polytechnic Society. The bones of elephant, hippopotamus, rhinoceros, bear, hyena, lion, bison, and other animals have been found in the quarries, and are now in the museum of the Leeds Philosophical Society.

The excursions gave great satisfaction to the visitors, and were the means of introducing many persons for the first time to a district remarkable alike for its geological features and its fine scenery. There were few opportunities for obtaining fossils, but some of the younger and more active members of the party applied their hammers at various points with considerable success.

INDEX.

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